# Robot Tray System

***ELEG/CPEG 480- Capstone Design Project II***

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Department of Electrical & Computer Engineering
AMERICAN UNIVERSITY *of* KUWAIT


June, 13th, 2021

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The capstone project report is being submitted in partial fulfillment of the requirements for the degree of

**Bachelor of Engineering in Electrical Engineering**

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## Declaration

We certify that this project work titled "*Title of the project*" is our own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources has been properly acknowledged / referred.

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# Copyright Statement

## Acknowledgements

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*"Devoted to our outstanding parents, cherished siblings and supportive friends who's without their enormous encouragement and immense collaboration our splendid achievement won't ever see the light of success."*

# Abstract

Nowadays, robotics technology is taking a larger role in our life. Robotics are being more involved in many aspects of our daily activities making our life easier, more comfortable and increasing its quality, efficiency and safety levels. They are being used in home automation, health services, constructions, agriculture and even to perform dangerous and accurate activities like working with dangerous chemical materials in different industries or in military operations like defusing bombs and mines. This project is about developing a robotic tray system that can be used in hospitals to serve patients, restaurants to serve tables, hotels to serve guests rooms and in many other places and applications. It consists of a robot that can deliver orders from a central point to different locations. This robot will be controlled by a mobile application that will give the user the option of controlling the robot manually or to determine a specific destination (table or room) for the robot to reach. The mobile application will communicate with a microcontroller on the robot through Bluetooth connection. The robot will follow a line that will be stuck on the floor, this line is made up of a regular tape that can be stuck or removed easily. The robot will follow this line to move forward using a line senor that uses IR connection to detect the line. When it reaches an intersection where there are two or more paths there will be an RF ID tag guiding the robot to its assigned destination where it will have an RF ID tag reader. When the robot reaches the destination, its microcontroller will turn on a buzzer on the robot to notify the customer that it arrived. When the customer takes the order, he will push a button on the robot making it go back to its central location. The robot will have the ability to detect obstacles on its path using an ultra-sonic sensor and it will turn on the buzzer when it faces one.



**Key Words:** *Bluetooth, Line Sensor, Microcontroller, RF ID Tag, Robotics, Tray Ultrasonic Sensor.*

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# CHAPTER 1: INTRODUCTION

## 1.1 Background

Nowadays, robotics technology is taking a larger role in our life. Robotics are being more involved in many aspects of our daily activities making our life easier, more comfortable and increasing its quality, efficiency, and safety levels. They are being used in home automation, health services, constructions, agriculture and even to perform dangerous and accurate activities like working with dangerous chemical materials in different industries or in military operations like defusing bombs and mines.

According to the international federation of robotics (IFR) the global average for industrial robots per 10000 thousand manufacturing workers grew from 66 to 85 between 2015 and 2017 [1]. In the near future with this exponential development in robotics technologies robots will continue to be smarter, flexible, energy efficient, and with more and more abilities to perform different kind of jobs in various fields. They will be able to do harder and more accurate tasks and challenges and this will make a significant contribution in securing the world supply chains.

Nowadays, with the pandemic of COVID-19 affecting all aspects of our life, limiting our freedom and slowing down the industries and economies robotics can be a great solution in helping us getting our normal life back again where they can the alternative in performing jobs and tasks that require direct contact between people and this will decrease the possibilities of infections and even robots can do these jobs and tasks in more accurate and efficient methods.

The technology of robotics is filled with promising progresses and developments that in past they were just dreams or only science fiction scenarios to us. Very soon we will see robots performing thousands of tasks and jobs that humans can never do alone from deep seas to the far outer space.

## 1.2 Problem Statement

Nowadays the world is facing the pandemic of COVID-19 where the most important action in facing this pandemic is the social distancing and decreasing contact between people everywhere. Weather in hospitals, restaurants or hotels we need the minimum contact between people to protect each other's from the transition of the infection. Providing services to guests in restaurants or hotels or to patients in hospitals by the same service workers will increase the possibility of spreading the infection.

With our proposed solution in this project the possibilities of transmitting the infection will be in its minimum levels and this will help in the battle against COVID-19 and will accelerate the virus eradication.

## 1.3 Aims and Objectives of the Project

The aim of this project is to provide a solution for restaurants, cafes, hotels and hospitals to provide their services to their guests with minimum contact between the guests and workers which will increase the social distancing and decrease the possibility of COVID-19 infection. The objectives of this project are:

1. To design and implement a robotic tray system by June 2021. This system can be used by hospitals, restaurants, cafes, and hotels to serve their guests tables or rooms. This system consists of a robot that can deliver orders from a central point to different locations by following a straight line and by reading RF ID tags to determine the desired location.
2. To design and develop a mobile application that can be used to control the robot manually and to assign a specific location for the robot to reach and it will communicate with the robot through Bluetooth connection.

## 1.4 Significance, Scope and Definitions

The proposed system in this project will significantly decrease the contact between the workers and the guests in hospitals, hotels, and restaurants and will decrease the contact between the guests themselves because in normal cases the worker can get infected from a guest and transmit the infection to another one but with our system this contact will be in its minimum levels.

Our scope in this project is to build a robot that can serve guests in hotels and restaurants and patients in hospitals and eliminate the need for an employee to do this job to ensure minimum contact and least possibility of COVID-19 infection where this robot will follow a special tray and read RF ID tags to reach its destination (table or room). This project will include research, design, hardware and software implementation and writing a paper about the whole work that could be published in future. At the end of this project, we will deliver a robot prototype and a mobile application to control and monitor this robot. The definition of a robotic tray system is any system that consists of a robot that follows a special route to reach its destination and deliver orders and go back to its central station automatically.

## 1.5 SWOT Analysis

In every project it is very important to do what is called a SWOT analysis which identifies the strengths which are the features and characteristics of the project that give it an advantage over other similar projects, weaknesses which are characteristics that are considered as disadvantages of the project compared to similar ones, opportunities which are factors the project could exploit to its advantage, and threats which are factors that could cause troubles for the project. These elements of the SWOT analysis are usually related to the business competition or the project planning. The Swot analysis of this project is illustrated in figure 1.

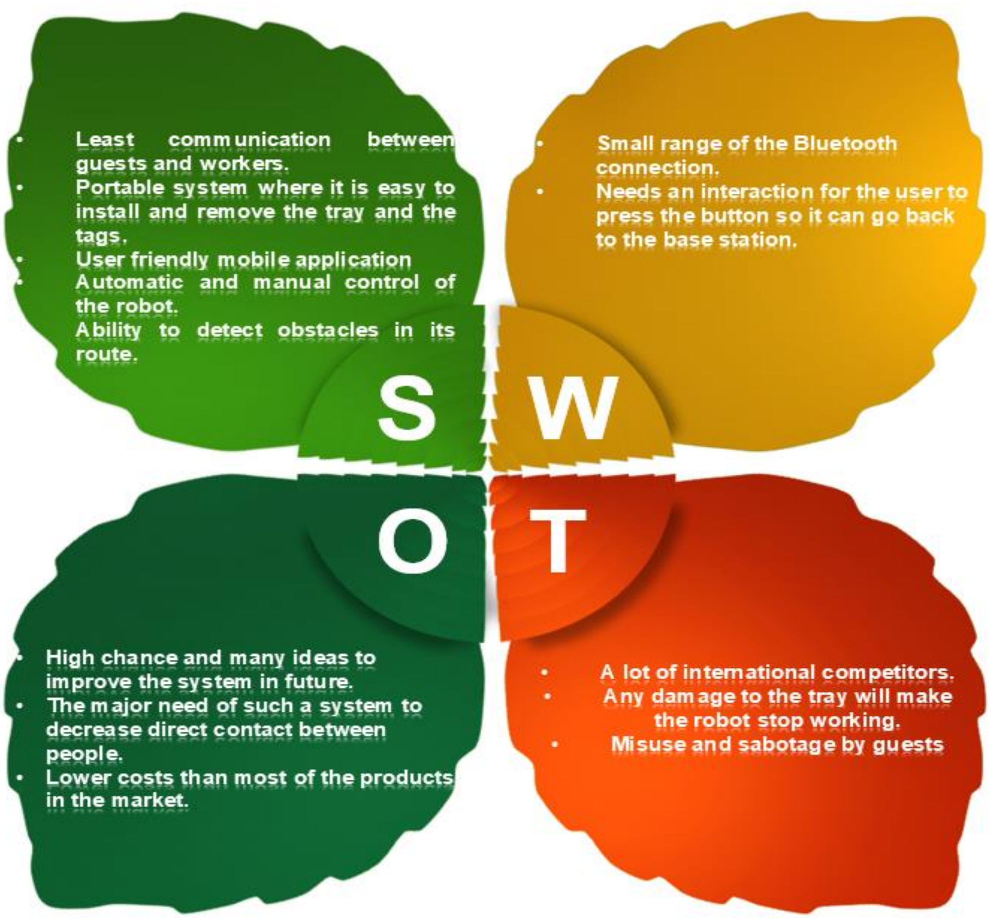


Figure 1.1: SWOT analysis of the project

## 1.6 Report Outline

This chapter included the introductory material for this project. In chapter two a literature review is done where student's papers, studies, and products similar to out proposed system are discussed and compared to each other. In chapter three the methodology of the work is defined, different design approaches are compared, and the chosen design is analyzed and discussed where block diagram is made, components are selected, and the cost of implementing the system is presented. Chapter four shows how the project was implemented in both software and hardware, the testing process, the used tools and resources, and the final results are all shown. Chapter five is an evaluation of the project where it shows how the end products meets the requirements of the system, a survey is made to evaluate the project from the users and potential clients' points of view and the impact of the project in terms of business, economy, social, and environmental impacts. Finally, in chapter six we made a conclusion about the project and presented some ideas that can be done in future to improve the system.

# CHAPTER 2: LITTERATURE REVIEW

## 2.1 Robotic Waiter System (BETA –G)

This robot is a mecanum wheel based robotic waiter that is used to serve tables in restaurants. This robot is free ranging one and it is designed to dock at the table where it rolls out the trays to the table instead of depending on the customer to take the tray from the robot. The trays are stored inside the robot to keep the food warm. This robot is modelled in ROS (robot operating system) which is a framework for software development for building robotic applications [2]. The robot consists of a base and an automatic dumb waiter. When the robot reaches a table a draw bridge is lowered and the required tray is lifted to the door and rolled out onto the table. The power source used for the robot is two 24V lithium polymer batteries. The robot is supported with a motorized lifting table, so it is capable of serving tables of different heights. The model of Beta G is created in ROS using the Undefined Robot Description Format (URDF). The robot motion is visualized in the RVIZ space which is a module that is used for path planning, navigation, and control [3]. The robot model is shown in figure 2.1.

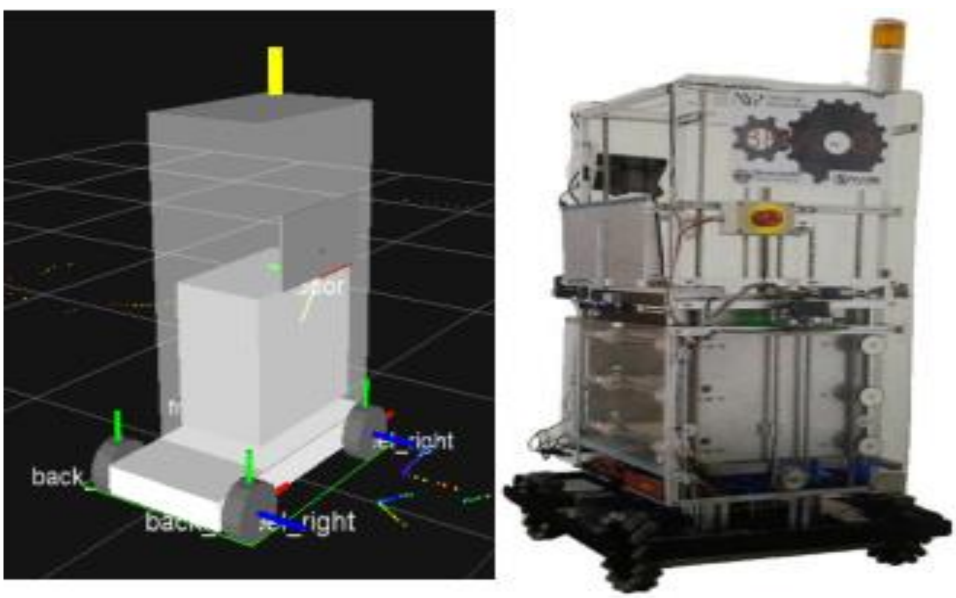

Figure 2.1: Beta G robot model [3]

## 2.2 Serving Robot with Double Line Sensors

This robot is designed with a control system that combines the proportional integral derivative (PID) controller with the pulse width modulation (PWM) method to help the robot to detect the smoothest path and it is robust to disturbance than the open loop control method. The robot is capable of serving the assigned tables and go back to its base following a line on the ground and it can avoid collisions during its motion. It consists of three parts; the base which is responsible of the robot movement and has the wheels and the motors, the body which has two trays to carry the customers' orders and the control panel that is used by the user to control the robot [4]. The robot prototype is shown in figure 2.2.

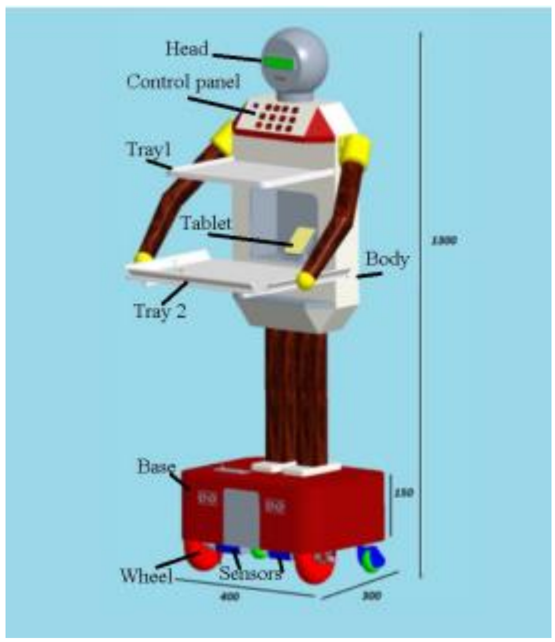


Figure 2.2: The prototype of the robot [4]

The robot has two microcontrollers which are PIC18F550 and it is used to control the motors and PIC 16F877A to select the desired table through an LCD screen. The power source used is a 12V, 12A battery which is regulated to 12V, 5A using LM2596 buck converter and to 5V, 2A using LM2576 buck converter. The 12V, 5A are used to control the motors through motor drivers and the 5V are used to power the microcontrollers. There are two line sensors, an ultrasonic sensor and sound module (speaker) connected to the PIC 18F550 controller. The other controller is mainly used for mapping data for the table's location and to navigate the robot to the desired tables. There is also an LCD screen connected to the PIC 16F877A controller. The block diagram of the whole system is shown in figure 2.3. The PIC 16F877A sends the readings of the line sensors and the ultrasonic sensor the other controller through the UART port so the PIC 18F550 control the motors through PWM and motor drivers to help the robot to stick to the lone and reaches the assigned table and avoid collisions. RF transceivers are used to make the robot return to its central location after serving the table [4].

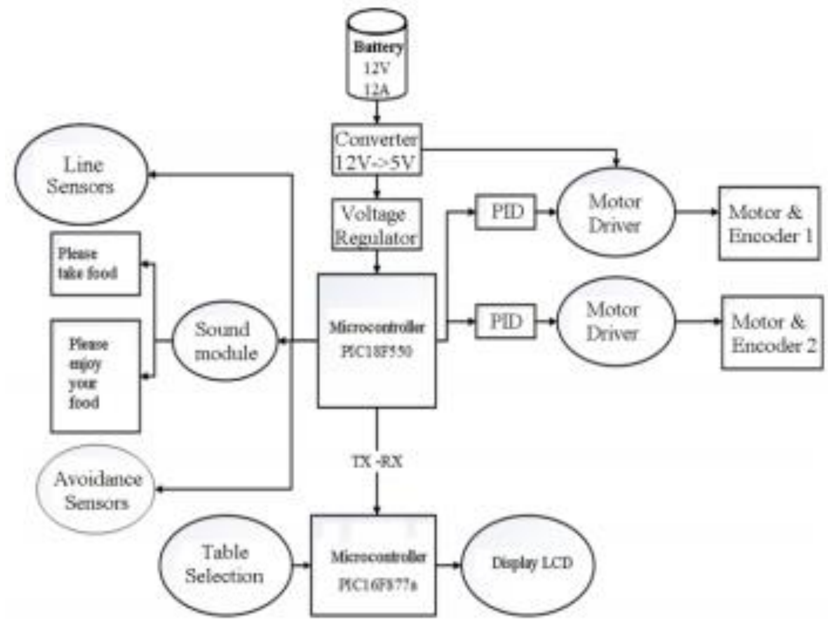


Figure 2.3: the block diagram of the system [4]

## 2.3 The Room Service Robot (Rose)

This robot is produced by company in California called Savioke. It is used in the Hotel Trio in Healdsburg, California to deliver snacks, towels, beers and bottles of wine to the guests in their rooms. It uses many sensors to smoothly move through elevators and hotels floors where it has a pre-downloaded map for the hotel rooms and corridors. It calls the room when reaches. It has a display that greets the guests when they open the door. A top compartment automatically opens so the guest can take his order. The company Savioke has manufactured many other robots for specific hotels using uploaded maps for each hotel to navigate the robot through it [5]. Rose robot is shown in figure 2.4.

Figure 2.4: Rose robot in Hotel Trio [5]

## 2.4 Wireless Waiter Robot

A waiter robot and a smart restaurant are designed to provide better services for customers. The robot can response to a lighting signal from any table in order to provide the restaurant services for that location. In addition, the customer can use an Electronic-Menu (E-Menu) which is embedded within the robot to select his/her order. The order will be sent to the kitchen and the food will be prepared. Consequently, it can be delivered to the determined table by the waiter robot. A credit card service within the same robot is suggested for payment purposes. The robot contains E-menu, Keypad, LCD display, Bluetooth and Arduino controller. The user checks the menu on the LCD display and places his order using the keypad where the order is sent to the kitchen and reception by Bluetooth. The keypad and the LCD are connected together by Arduino technology. Figure 2.5 shows the essential parts of the E- menu [6].

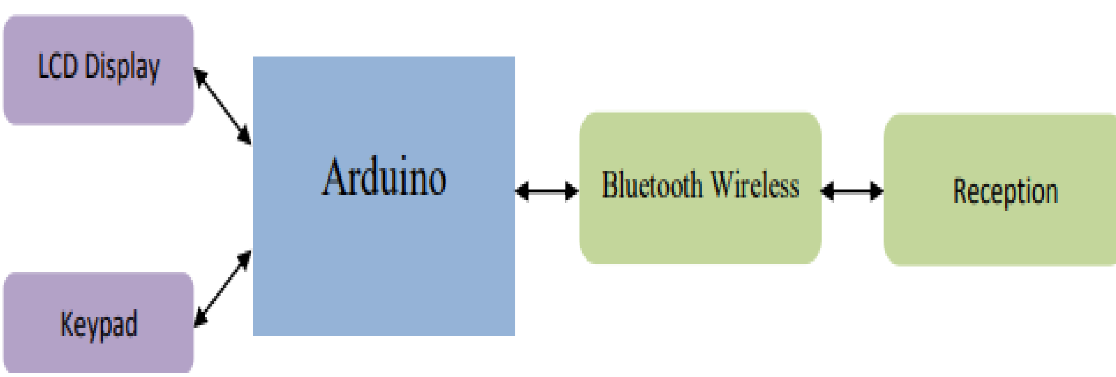


Figure 2.5: The block diagram of the E-menu [6]

A special arrangement is made for the table in restaurant as shown in figure 2.6 where a squared track for the waiter robot movements is designed. The robot waiter will follow the service line (or track). Four Infrared (IR) sensors are required: two center sensors and two side sensors. The two center sensors are for tracking the service line. The two side sensors are utilized for table counting. That is, if the robot counts one this means that it has been stopped near the first table and if the robot counts two this means that it has been stopped near the second table, and so on [6].

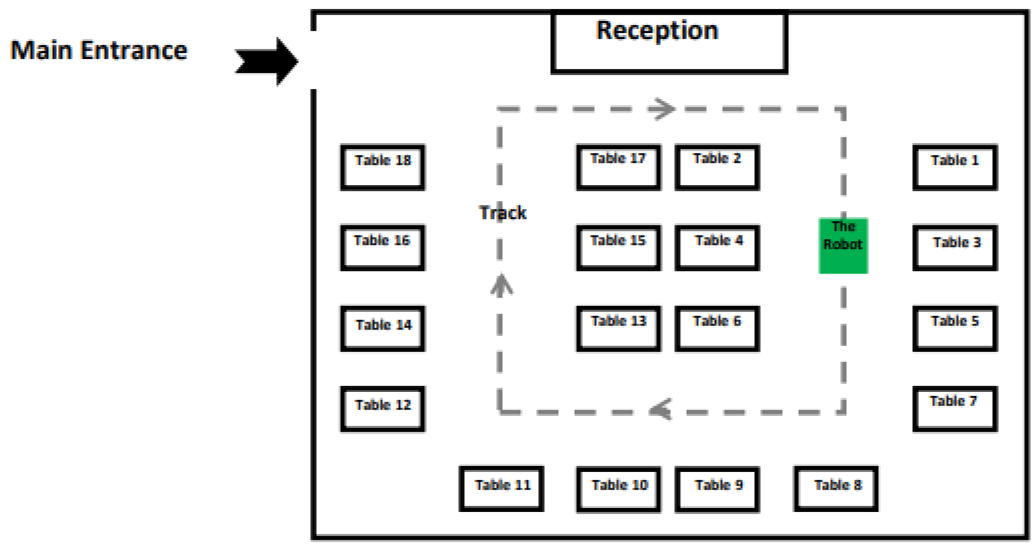


Figure 2.6: Tables arrangement and the robot track [6]

## 2.5 Robotic Waiter

In this project the restaurant ground will consist of the black lines, LED lights and the tables will have switches. LEDs will be placed on the path of robot. When the customer comes he will press the button to get refreshment. As the button will be pressed (switch is on), the LED at the starting point and the LED at the junction from where robot will move to serve towards the table will glow. As the LED at starting point will glow the robot will initiate its program to follow black line. The robot will start following black line, when it finds a white light in the way it will turn left or right accordingly and serve the refreshment. After serving it will again follow the returning black line path and go back to the starting position as shown in figure 2.7. The used robot is the Firebird V ATmega 2560 robot. This robot is fully automated. It has 3 white line sensors on it. Whenever the middle sensor will sense black color and other two white the robot will move forward. Whenever the values of the other two sensors changes this means that the robot has to take a decision to turn left or right [7].

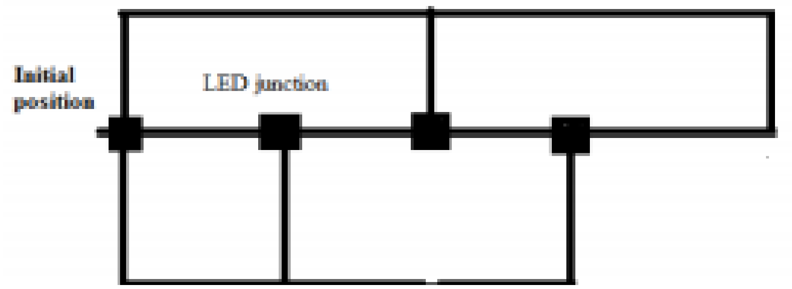


Figure 2.7: The robot path [7]

## 2.6 Intelligent Robotic Waiter with Menu Ordering System [8]

This project is about building an environment of a restaurant where a robot fulfils the role of dealing with customers. A menu card is provided using android application. The order will be sent to the counter consisting of laptop through Wi-Fi link and the details will be saved in the database of the counter. Once the order is ready to be served the robot will be informed and it will deliver order from the counter to the required table. The robot uses a precise control mechanism using coordinate mapping method to reach the customer table. Figure 2.8 shows the block diagram of the system.

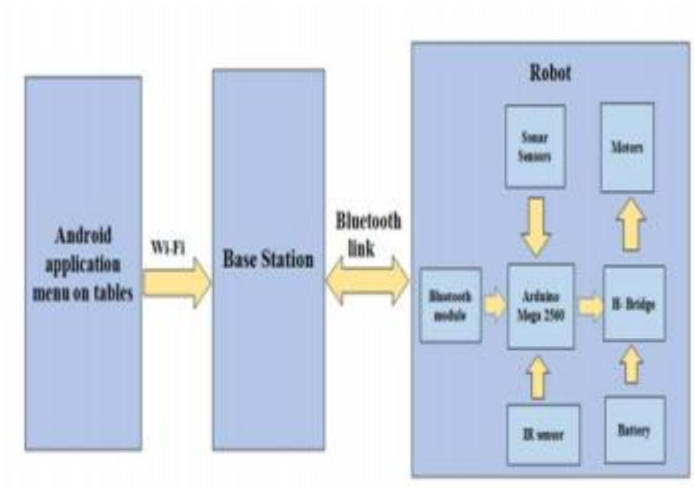


Figure 2.8: The block diagram of the system [8]

The Waiter robot is fully autonomous and works without the interference of any human being. Once the environment of the restaurant is set the waiter will await the instructions from the counter in response to the order sent from the table. On the tables smart phone devices are placed were they features the meals offered by the restaurant. The customer selects any food item from the menu card through smart phone that will be send via Wi-Fi, containing exact table number with item selected, to the counter. All the information of the table will be shown in the database at the counter just as the table number, time, date, items ordered, order number and total price [8].

The robot structure is equipped with electronic circuits, power supply, Arduino mega 2560, ultrasonic sensors, IR sensor, Bluetooth shield and DC gear motors. The ultrasonic sensors are installed on the front and on one side of the robot in order to detect the obstacles in front of it and on the sides as well. A tray like section is premeditated inside the robot where the food items can be placed so that robot can carry them to required tables. When the database receives the order coming from any of the tables it will transmit the command which is defined for the tables. For each table there is a separate command transmitted to the robot via Bluetooth shield HC-05, in this way the robot senses to which table it has to deliver the order. After the command is sent to the robot, it will move toward its required destination through a dedicated mapped path. If any obstacle comes in its way it will sense the obstacle through its ultrasonic sensor by generating echoes, the robot will then stops and wait for some seconds and changes its path to reach its destination. If the path of the robot would be blocked from two sides with the obstacles then it will wait for some seconds and then will ring its buzzer. Otherwise it will move towards its required destination, delivers the order and moves to the counter to complete its path [8].

## 2.7 Simple Delivery Robot System Based on Line Mapping Method [9]

The robot used in this project has a dimension of 40 cm (length) x 40 cm (wide) x 40 cm (height), it can be summoned from several rooms using RF remote and can be ordered to deliver things and send messages. The robot uses seven infrared sensors to trace the line path which is within 1.5 cm from underneath its body. The robot can go to four designated rooms plus one base camp. The robot also has several features i.e.: alarm system which can indicate when the robot arrived at the destination, LCD and keyboard so the user can write message, obstacle sensor to avoid crash, and emergency system which will active when the robot stray out of the line. The emergency system activates video camera and alarm so the user can control the robot with remote control to position it back in the line map. All activities are controlled by microcontroller AT89C51. Figure 2.9 shows the block diagram of the robot.

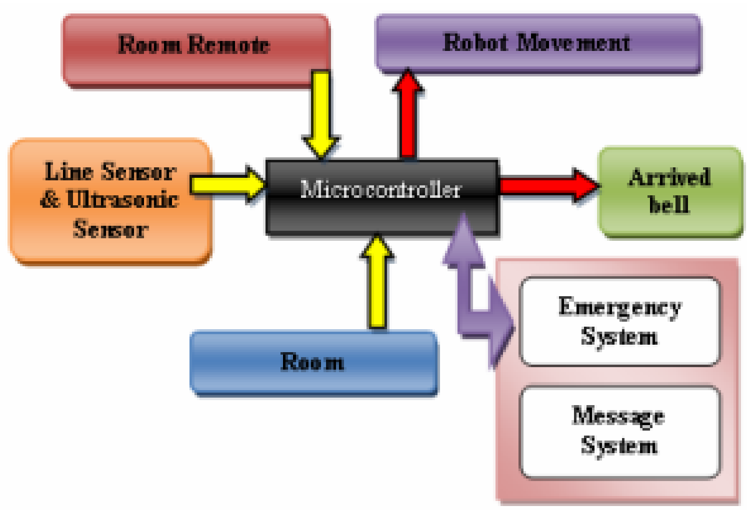


Figure 2.9: Robot block diagram [9]

## 2.8 Summary and Implications

Table 2.1 shows a comparison between the discussed topics in this chapter.

Table 2.1: Literature review summary

| Topic | Strengths | Drawbacks |
| --- | --- | --- |
| **Robotic Waiter System (BETA –G)** | • Free Ranging<br>• Rolls the trays to the table<br>• Keeps the food warm<br>• Can serve tables with different heights | • No mobile application to monitor and control the robot remotely<br>• No obstacles detection ability |
| **Serving Robot with Double Line Sensors** | • Line path followed using line sensors.<br>• Control panel and LCD to select the table<br>• Communicates with customers through voice commands<br>• Detecting obstacles capability | • No mobile application to control and monitor the robot remotely<br>• Changing table locations needs reprogramming the system and redoing the mapping |
| The room service robot (Rose) | • Uses a lot of sensors to move smoothly | • Every robot is built for a specific hotel |

| | | |
|---|---|---|
| | through elevators and floors<br>• Call the guest room when it arrives<br>• Display to greet the guest | • Pre-downloaded map so when the pace changes we need to download a new different map by a specialist<br>• No mobile application to control and monitor the robot |
| **Wireless Waiter Robot** | • Robot responses to lighting from any table<br>• E-menu embedded in the robot and the user can see it on LCD<br>• The user can make order using keypad<br>• Credit card payment service | • Needs special table arrangement in the restaurant<br>• Different guests use the same keypad which increases the possibility of COVID-19 infection |
| **Robotic Waiter** | • Tables have switches to call the robot<br>• Follow black lines tray and glowing LED lights | • No mobile application to monitor and control the robot<br>• Needs high maintenance for LED where if one is damaged the robot won't be able to go through the right path |
| Intelligent Robotic Waiter with Menu Ordering System | • Obstacles detection and avoidance<br>• Android application menu<br>• Fully autonomous operation | • Uses coordinate mapping for tables so if the table location changes we need to reprogram it.<br>• No manual control of the robot is available |
| Simple Delivery Robot System Based on Line Mapping Method | • LCD and keypad for the user to write messages | • Destination limited to four rooms only |

| | | |
|---|---|---|
| | • Obstacles detection<br>• Emergency system when the robot is out of line | |

# CHAPTER 3: METHODOLOGY, DESIGN AND ANALYSIS

## 3.1 Methodology

The Methodology in any project is the design process and the procedure followed to complete a project. The first step is determining the requirements of the system we want to build. Requirements include the needed features and characteristics and client needs. The next step is the design where different solutions are discussed and the one which meets the project requirements the most will be chosen, then this chosen solution is analysed, block diagrams and flowcharts are made, system components and needed parts are selected, and a schematic diagram of the system is drawn. When the design step is finished the next step is the implementation in both hardware and software levels where hardware components are assembled, codes are written and the whole system is being built. The final step is the testing of the implemented design to discover any errors in the har4dware or software and fix them in order to deliver the complete system in its best condition. The methodology of our project is summarized in figure 3.1.

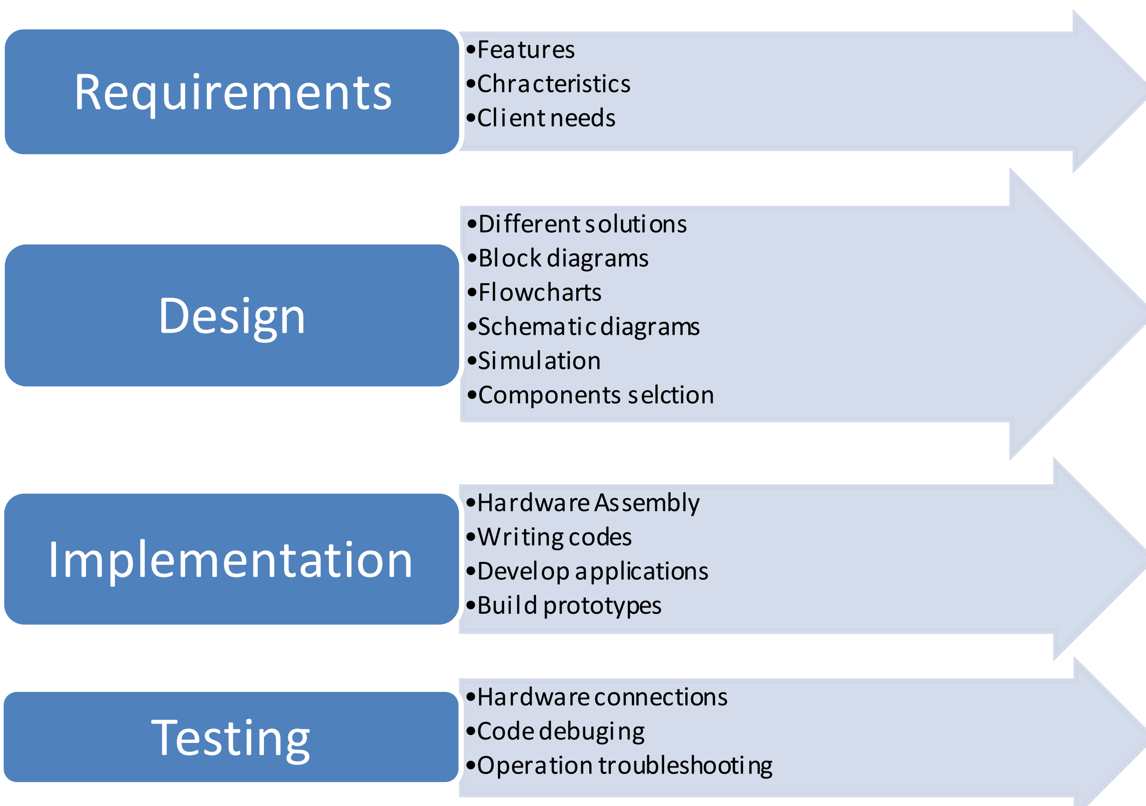


Figure 3.1: Project Methodology

## 3.2 Research Design

The requirements of the system are mentioned below:

- The system will consist of a robot prototype
- The path of the robot will be a line tray fixed on the ground
- The line tray shall be removed and re-installed easily
- The robot path must lead to the tables or rooms in restaurant, hotel, or hospital
- The robot shall be able to reach the destination assigned by the admin of the system
- The robot shall be able to detect obstacles in its route
- The robot must return to its central station after delivering the order
- The robot shall be able to be controlled remotely and manually by an admin

In the next two sections we will discuss two different solutions and choose the more suitable one that can achieve the requirements of the system better than the other.

### 3.2.1 Line path with RF ID tags, LCD and keypad on the robot

In this design solution the robot will have a keypad and an LCD where the admin can determine the destination of the robot (table or room number) using the keypad on the robot. The robot will have a line sensor to follow the line path fixed on the ground and it will have the ability to detect obstacles in its route where it stops and turn on a buzzer to indicate that something is blocking its way. The path of the robot will have RF ID tags and the robot will have an RF ID reader to read the tags and reach its destination. It will have a push button for the guest to push when he takes his order so the robot can return to its spectral station. This solution is shown in figure 3.2.

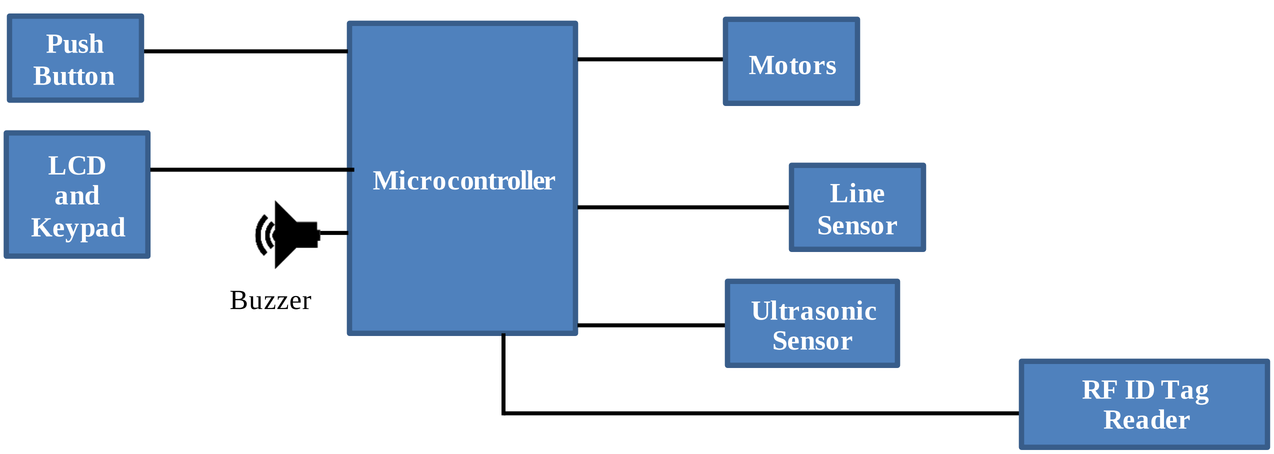


Figure 3.2: The architecture of the first design solution

### 3.2.2 Line path with RF ID tags and an admin mobile application

In this solution the path of the robot will also have RF ID tags and the robot will have RF ID reader to reach its destination. The robot will also have the ability of detecting obstacles in its route and turn on a buzzer to indicate that. In this solution there is a mobile application the admin can use it to control the robot manually and to determine the destination for the robot so it can go to it automatically. When the robot reaches the destination and the guest takes his order he will press button on the robot so it can go back to its central station. This solution is presented in figure 3.3 below.

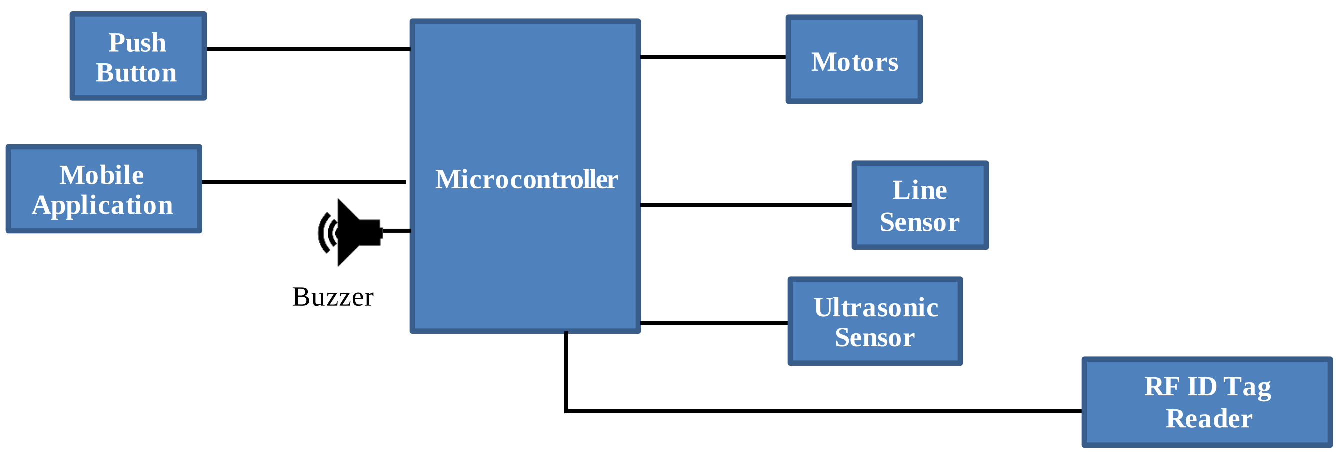


Figure 3.3: The architecture of the second design solution

## 3.3 Analysis

The second solution gives the user the ability to control the robot manually and remotely in addition to the automatic control method. Choosing the robot destination using a mobile application is a better method than the keypad and LCD where the user can choose the destination wirelessly and it is better to not touch the robot to decrease the possibility of COVID-19 transmission. So, the chosen design solution is the second one.

Basically, the system consists of a robot vehicle that follows a line path on the floor. This path leads to the tables or rooms that the robot has to reach and deliver orders by the order of the user. The path is made up of a regular tape that can be installed and removed easily where the robot will follow it using a line sensor installed on the bottom of its body and it will start its journey from a base point. Figure 3.4 shows an example of a path in a restaurant.

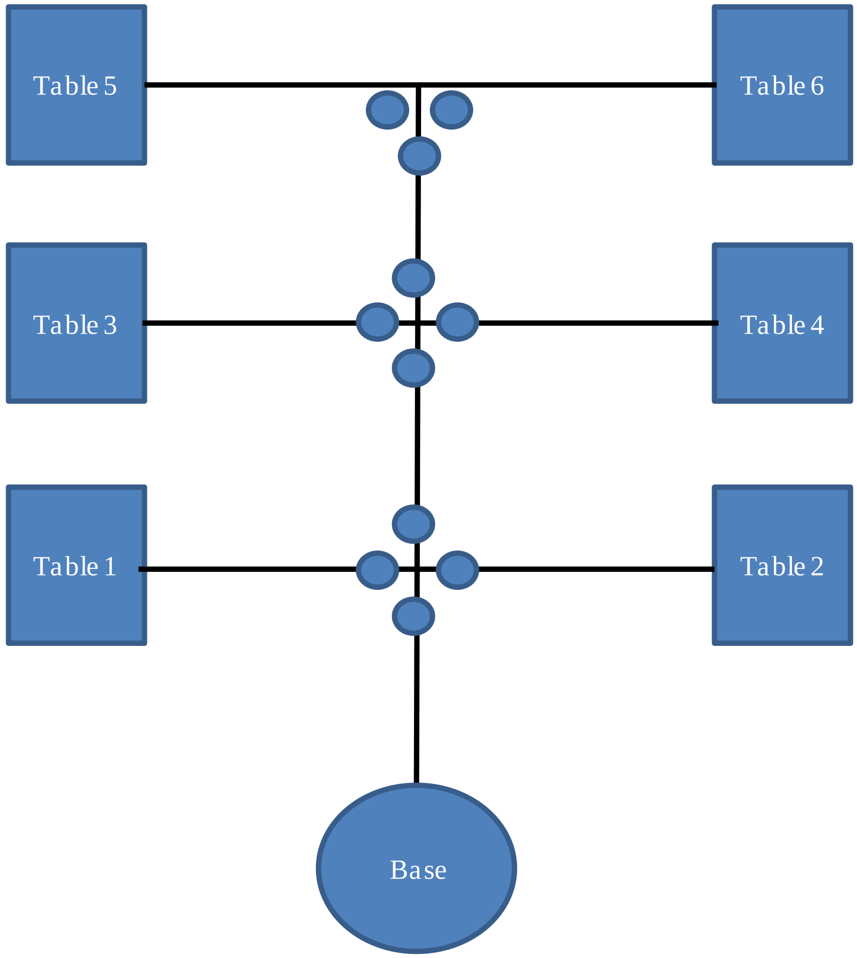


Figure 3.4: The robot path

As you can see in figure 3.4 the path starts from the base point and leads to the six tables in the restaurant. When the robot has an order to deliver something to any of the tables it starts following the line. When it reaches an intersection the robot decides its way be reading the RF ID tags placed on the intersection which are represented by the small circles in figure (10). Each tag has the number of the table at its side. The robot reads the tags and compares the reading with the assigned number by the user to find the desired table and move towards it. After the robot reaches the desired table it turns on a buzzer to notify the guest that the order is arrived. The guest takes the order and presses a button on the robot where the robot turn around and goes back to its base location. A block diagram of the robot is shown in figure 3.5.

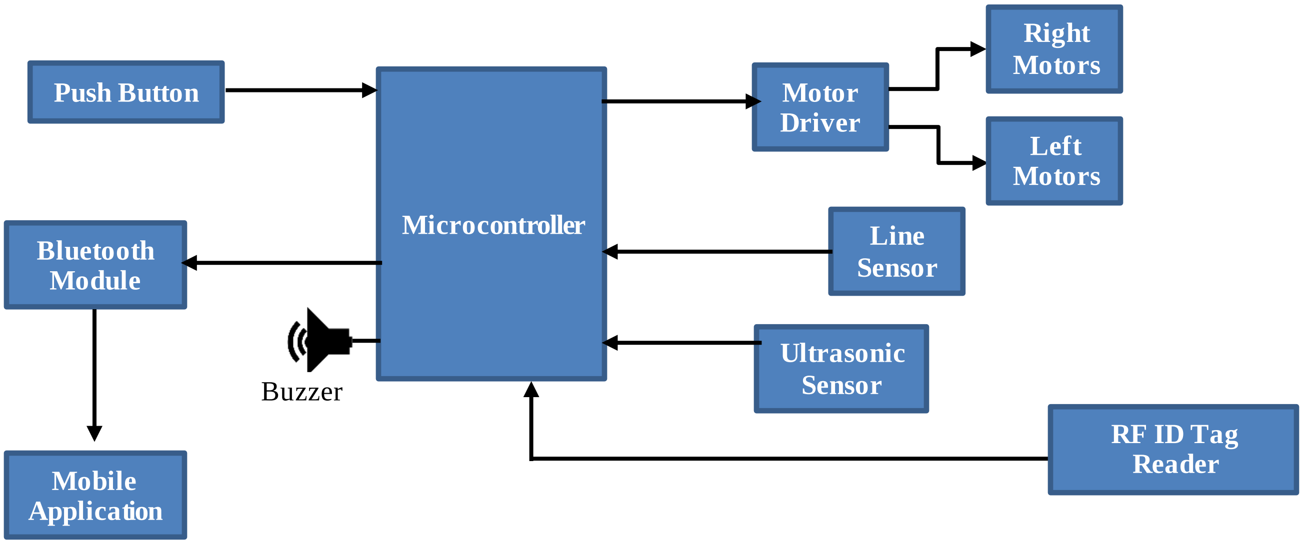


Figure 3.5: System block diagram

As you can see in figure 3.5 the robot has a microcontroller which monitors and controls the whole operation of the system. The robot consists of four wheels vehicle that uses DC motors to move. The motors are connected to the microcontroller through a driving circuit because the power that can be supplied through the microcontroller is less than the power needed by the motors to operate. There is also the line sensor connected to the microcontroller where it is installed at the bottom of the robot body and it is used by the robot to detect the line which is the path of the robot. An ultrasonic sensor is used so the robot can detect obstacles on its way where it will be programmed to stop and turn on the buzzer connected to the microcontroller to notify the user that there is an object blocking its way. A push button will be used by the guest of the restaurant or the hotel after taking their order to make the robot go back to its base point. There is an RF ID tag reader used by the robot to read the tags on the floor to reach its desired location. The robot will be supplied by lithium batteries that are connected to a voltage regulator that will give us 5V which is the voltage needed by the microcontroller to operate. The communication between the robot and the user will be done through Bluetooth connection where the robot will receive orders by the user on a mobile application by using a Bluetooth module connected to the microcontroller as you can see in the block diagram in figure 3.5 above. The graphical user interface (GUI) of the mobile application that communicates with the robot through Bluetooth connection as mentioned before is shown in figure 3.6.

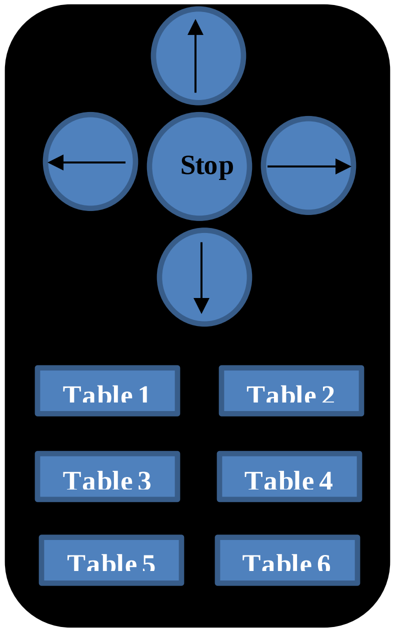


Figure 3.6: The GUI of the mobile application

As you can see in figure 3.7 the GUI of the system gives the user the ability to control the robot in two ways; manually by using the buttons with the arrows and the stop button or automatically by pressing one of the buttons with table's numbers where the robot is programmed to reach the location once the user hits the button.

## 3.4 Hardware and Software

**1) Line Sensor**

The chosen module is shown in figure 3.7. It is a high efficient three way line tracking module. It has three TCRT5000 infrared line tracking sensors with on-board comparator, LED indicators and other signal conditioning components. This module uses infrared to detect the line so it has anti-interference ability where visible light will not interfere its operation. The TCRT5000 is a reflective sensor which include an infrared emitter and a phototransistor in a leaded package which blocks visible light [10].

Figure 3.7: The line sensor module [10]

**2) Ultrasonic Sensor**

The chosen module for the ultrasonic sensor is the HC-SR04 module shown in figure 3.8. This sensor operates at 5V which means it can be directly connected to the microcontroller. It has a practical measuring distance between 2cm and 80cm with an accuracy of 3mm.and it cover up to 15° angle [11].


Figure 3.8: HC-SR04 module [11]

**3) Robot Chassis**

The chosen robot is the DIY Robot Smart Car Chassis Kit with Speed Encode shown in figure 3.9. The size of this robot vehicle is 25cm * 14cm (L* W), it has four 6cm * 2.7cm (Dia. * H) wheels and it has four DC gear motors. This chassis is an eco-friendly chassis with flexible turning ability. It has high stability and it is very easy to expand [12].


Figure

Figure 3.9: The chosen robot chassis kit [12]

**4) Motor Driving Circuit**

The chosen module is the L293D shown in figure 3.10. This circuit is used to supply the motors with the needed power to operate. It has an input voltage between 4.5V to 25V DC and 600 mA output current capability per channel. It also has high noise immunity and internal clamp diodes [13].

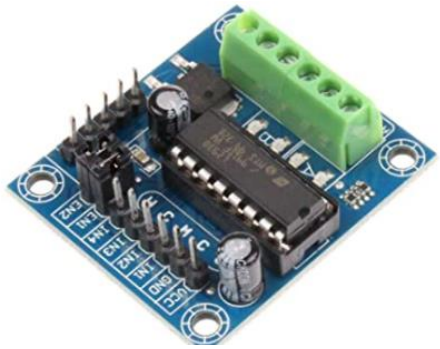

Figure 3.10: L293D module [13]

**5) Microcontroller**

The chosen microcontroller is the Arduino UNO shown in figure 3.11. It is a microcontroller board based on the ATmega328P, it has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller. It can simply be connected to a computer with a USB cable or can be powered with AC-to-DC adapter or battery to get started. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform [14].

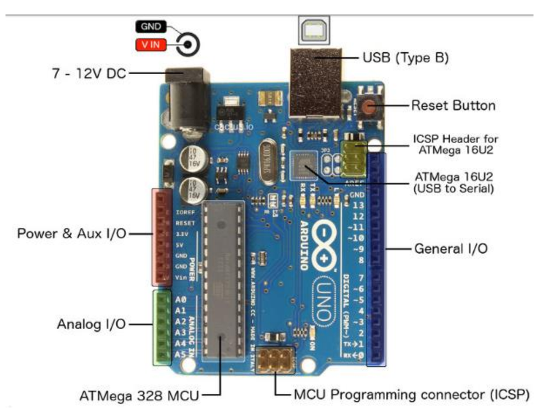


Figure 3.11: Arduino UNO board [14]

## 6) Bluetooth

The chosen module for the Bluetooth connection is the HC-06 module shown in figure 3.12. This module has an operating voltage between 3.6V and 6V, it has small size, low power consumption, high sensitivity for send and receive [15].

Figure 3.12: Bluetooth module [15]

## 7) NFC tag reader

The chosen module for the RF ID reader is PN523 reader/writer shown in figure 3.13. It is an Arduino compatible module that can read and write to all ISO14443A/B compliant RFID and NFC tags [16]. It has many features such as [16]:

1) Small dimension and easy to embed into your project.

2) Supports I2C, SPI, and HSU (high speed UART) and it easy to change between these modes.

3) Supports RFID reading and writing, P2P communication with peers, and NFC with android phones.

4) Up to 7cm reading distance.


Figure 3.13: NFC tag reader [16]

For the software part we will use the Arduino IDE software and Arduino libraries for interfacing the selected components with the microcontroller of the system, and the code will be written using the C++ language and then uploaded to the controller.

Table 3.1 shows the cost of implementing the system and the bill of materials.

Table 3.1: The BOM of the system

| Component | Module Number | Quantity | Cost ($) | Supplier |
|---|---|---|---|---|
| Line Sensor | TCRT5000 | 1 | 6 | Amazon |
| Ultrasonic Sensor | SR-04 | 1 | 10 | Amazon |
| Robot Chassis | DIY Robot smart car chassis | 1 | 27 | Amazon |
| Motor driving circuit | L293D | 1 | 7 | Amazon |
| Microcontroller | Arduino UNO | 1 | 35 | Amazon |
| Bluetooth | HC-06 | 1 | 12 | Amazon |
| NFC Reader | PN523 | 1 | 33 | Amazon |
| RFID Tags | --- | 50 pieces package | 23 | Amazon |
| Wires, circuit components, etc. | --- | --- | 40 | Amazon |
| Lithium Battery | 3.7 V, 2200mAh | 2 | 55 | Amazon |
| **Total** | 248 $ | | | |

- **Prices in U.S dollars as it is a worldwide currency.**

## 3.5 Ethics and Limitations

During the design, implementation, and testing stages of the project the team will work in high manners to ensure the integrity and dignity of the profession of engineering .The team will make sure that the system implemented in this project is safe for both the team members who are building it and the end users who will use it when it is completed where the team will ensure that the system will not have any bad impact on the on the health and safety of the users. The team will also work hard to follow all the IEEE codes of ethics and that the project will not harm the surrounding environment in any way.

# CHAPTER 4: IMPLEMENTATION

## 4.1 Hardware Implementation

The project build up will be discussed in this section of the report, the buildup process started by assembling the robot chassis including the four dc-motors then we implemented the power supply for the robot and the next step was to connect the sensors as will be discussed.

### 4.1.1 Motors Implementation

The motor driver L293D can drive two channels dc-motors, we have connected the right motors to one channel and the left motors to the other channel, in this way Arduino board can control each side of the robot separately, in this way the control signal of the right side can be different from the left side and the controller can steer the robot in all directions.

For each motor channel there are three control lines, at which two for direction control and one for enable/disable the channel, figure 4.1 below shows the final motor schematic.

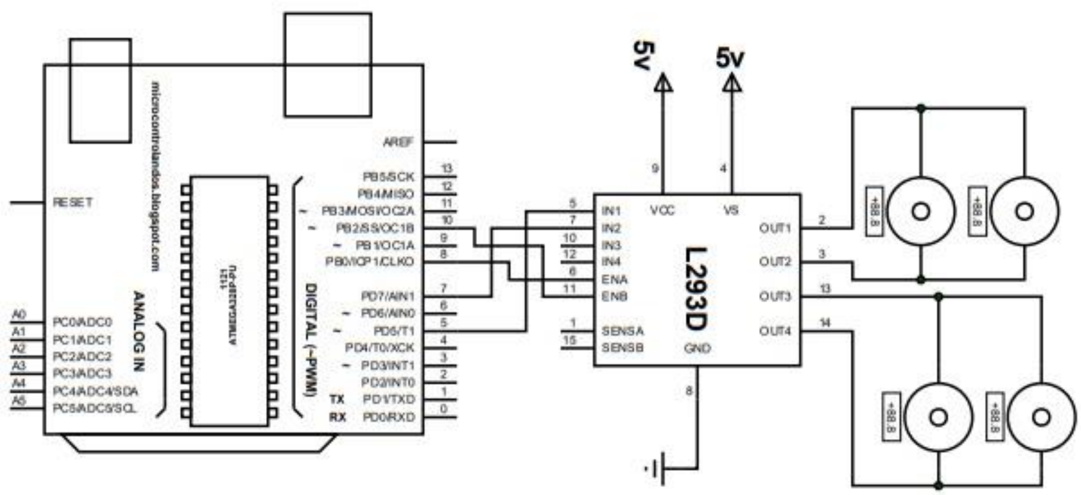


Figure 4.1 Motors implementation

### 4.1.2 Battery Connection

Lithium battery is used because of its light weight and its high storage capacity, the two series cells will give 7.4V which is higher than the operation voltage of the sensors and Arduino, for this purpose we used the LM2596 to step down the voltage to 5volts as shown in figure 4.2 below.

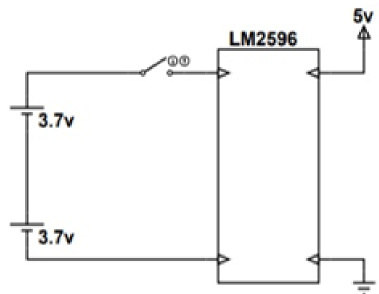


Figure 4.2 Battery connection

### 4.1.3 Buzzer Implementation

The buzzer can be directly connected to the Arduino board using one of the digital output pins on the Arduino, figure 4.3 below shows the buzzer schematic where it is connected to digital pin A3.

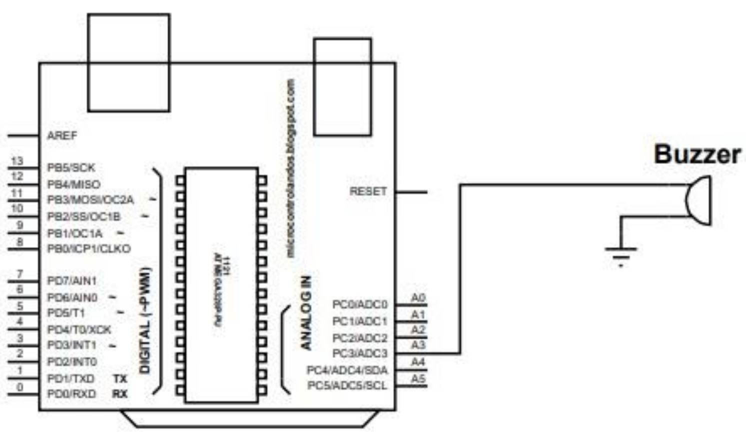


Figure 4.3 Buzzer connection

### 4.1.4 Near Field Communication Reader Implementation

NFC reader is used to read the tags to give the robot the destination numbers, it operates on 5volts and it is being powered from the buck converter 5volts output, the communication for the NFC reader is I2C so it should be connected to SCL and SDA pins on the Arduino board as show in figure 4.4 below.

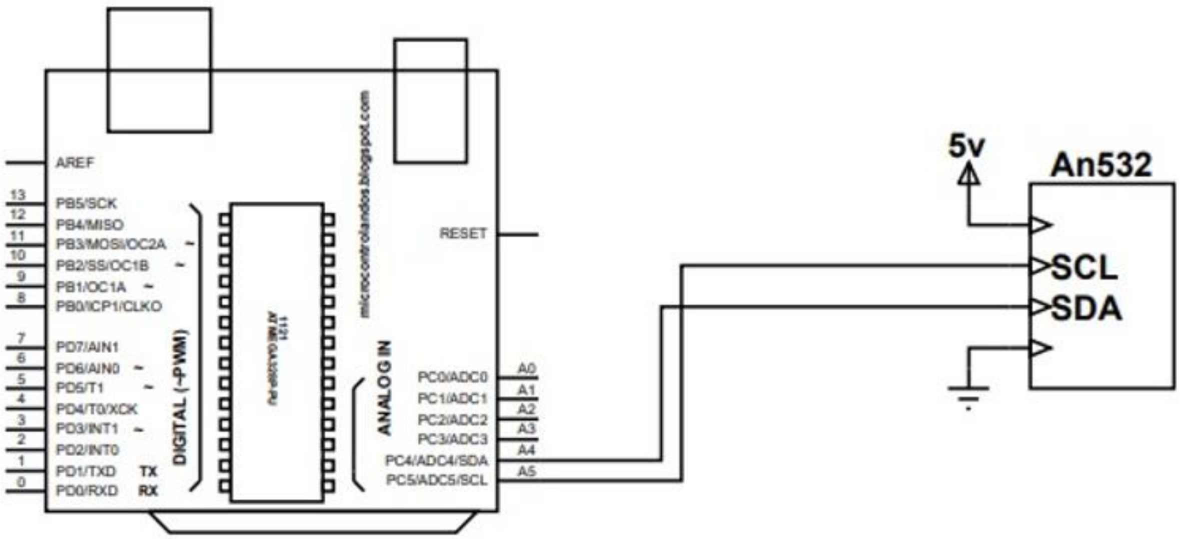


Figure 4.4: Near Field Communication reader implementation

### 4.1.5 Ultrasonic Sensor Implementation

Ultrasonic sensor is used in this system to avoid collisions while the robot is moving, the sensor has to be triggered from the Arduino board using the trigger pin that is connected to D4, then the sensor will give a pulse on the echo pin that represent the time of flight for the sound wave, and by measuring this time we can calculate the distance since the speed of sound is known (343m/s) the echo pin is connected to D11 as shown in figure 4.5 below.

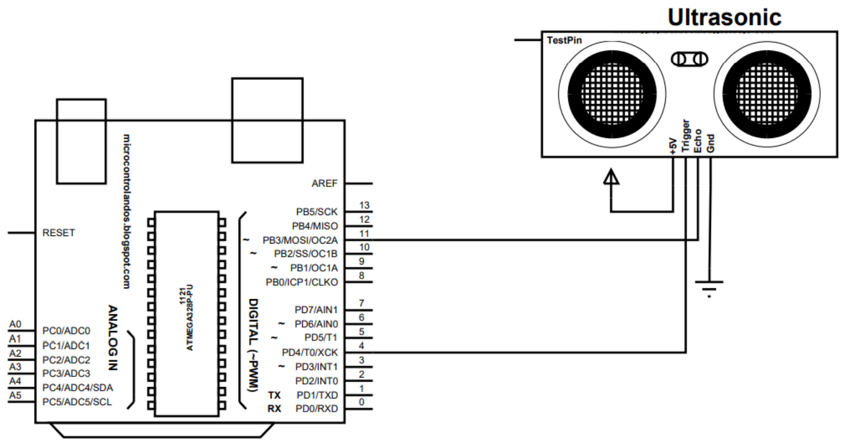


Figure 4.5: Ultrasonic sensor connection

### 4.1.6 Line sensor implementation

The robot is designed to follow the black line, for this purpose we used three IR sensors for detecting the black line, left sensor to steer the robot to the left and the right sensor will guide the robot to the right and finally the center sensor will guide the robot to move forward.

The three sensors are implemented on the same PCB where there are one output for each sensor, in our system we have connected the center sensor to A1 and the right sensor to A0 and finally the left sensor to A2 as shown in figure 4.6 below.

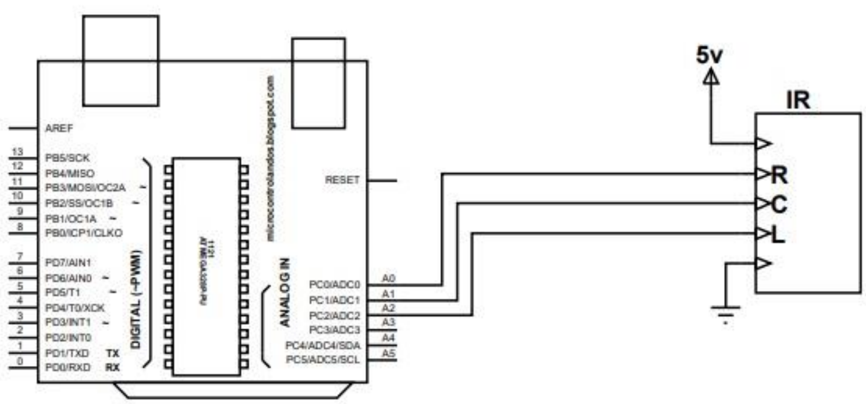


Figure 4.6: Line sensor connection

### 4.1.7 Push Button Implementation

The push button is implemented in this system for the user or client, he can take hs order from the robot and press the button for the robot to go home, the button has two pins where one button is connected to ground and the other pin is connected to D12 as shown in figure 4.7 below, when the button is pressed a digital zero will be fed to D12 indicating that the button pressed.

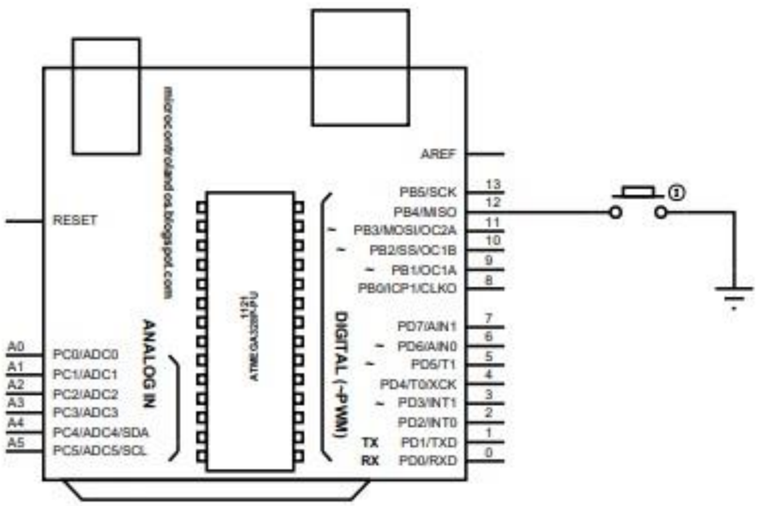


Figure 4.7: Push button connection

### 4.1.8 Bluetooth Implementation

The robot needs to be connected with the mobile applications, the best way for the connection is to use the Bluetooth since it is already built in the mobile phones, the HC-06 module can be connected to the mobile phone wirelessly from one side and connected to the Arduino board using serial protocol from the other side.

Serial protocols requires two pins one is the transmitter and the other is the receiver as shown in figure 4.8 below.

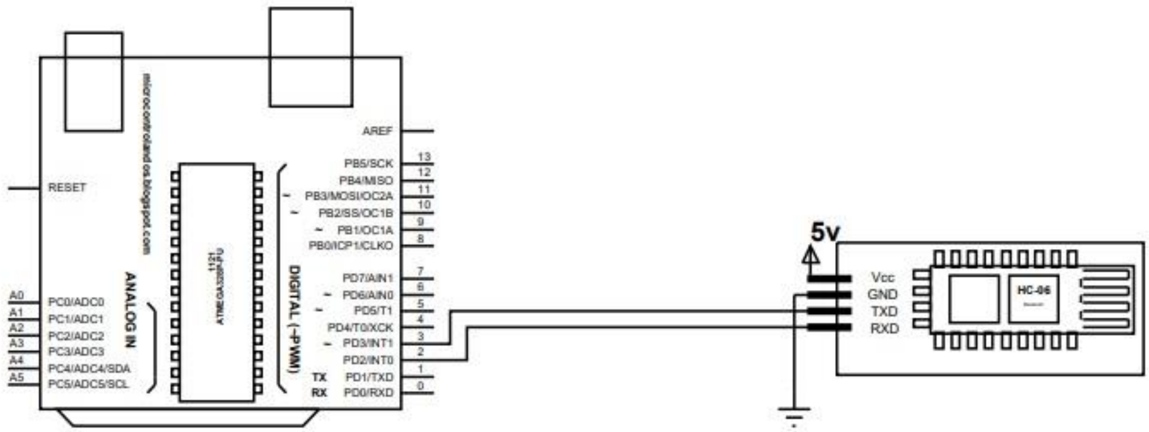


Figure 4.8 Bluetooth implementation

## 4.2 Software Implementation

### 4.2.1 MIT application

MIT App Inventor is an online platform designed to teach computational thinking concepts through development of mobile applications. Students create applications by dragging and dropping components into a design view and using a visual blocks language to program application behavior

MIT App Inventor is a web application integrated development environment originally provided by Google, and now maintained by the Massachusetts Institute of Technology (MIT).

The Design Window, or simply "Designer" is where you lay out the look and feel of your app, and specify what functionalities it should have. You choose things for the user interface things like Buttons, Images, and Text boxes, and functionalities like Text-to-Speech, Sensors, and GPS as shown in figure 4.9.

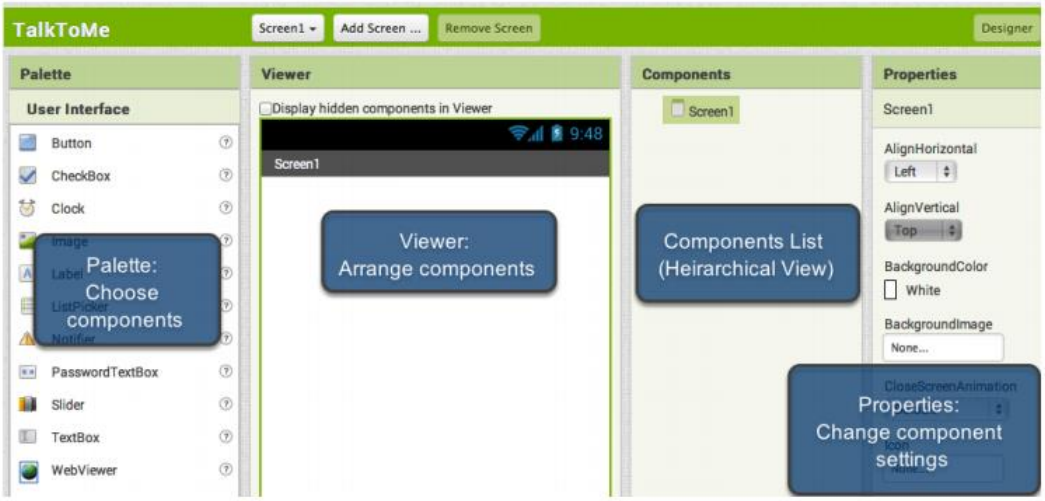


Figure 4.9: The environment of the MIT application

Our project needs a button. Click and hold on the word "Button" in the palette as shown in figure 4.10. Drag your mouse over to the Viewer. Drop the button and a new button will appear on the Viewer.


Figure 4.10: Adding a button to the GUI

### 4.2.2 The Blocks Editor

The Blocks Editor is where you program the behavior of your application as shown in figure 4.11. There are Built-in blocks that handle things like math, logic, and text. Below that are the blocks that go with each of the components in your app. In order to get the blocks for a certain component to show up in the Blocks Editor, you first have to add that component to your app through the Designer.

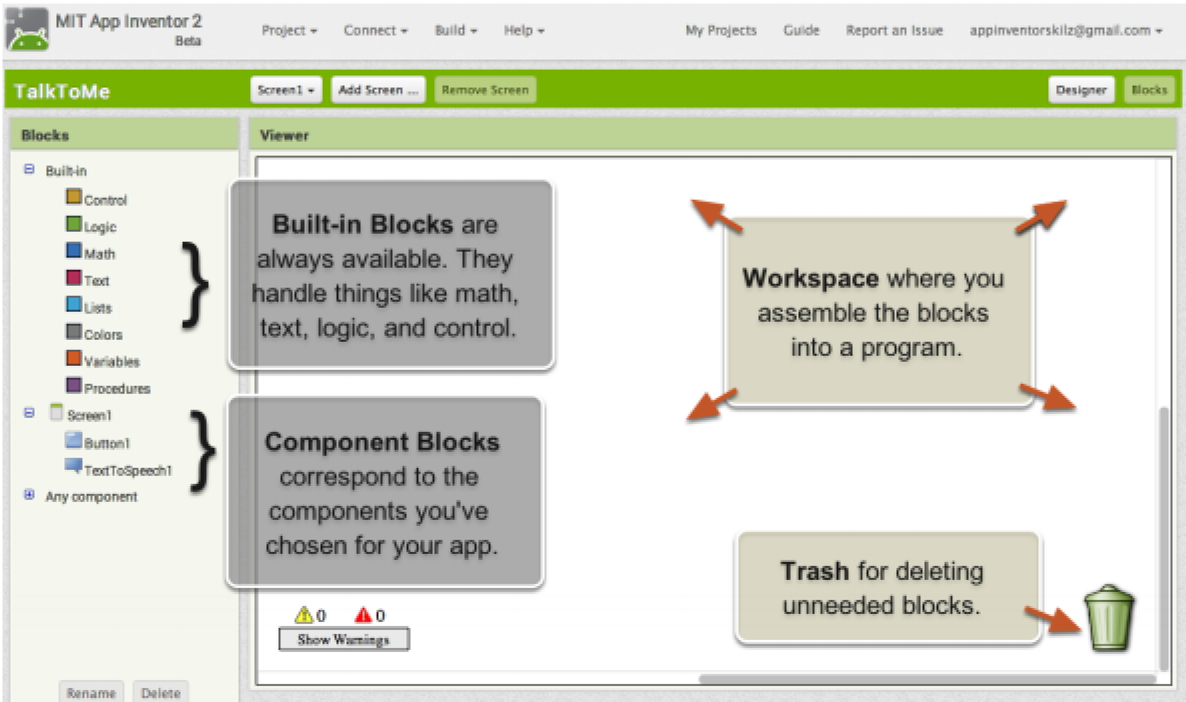


Figure 4.11: The blocks editor

### 4.2.3 Graphical user interface

User should connect the mobile application to the robot before start using the GUI buttons shown in figure 4.12, this can be done using the connect button where all the available Bluetooth devices will be displayed and the user can choose the desired Bluetooth module then the robot can be controlled in two modes as follows:

**Manual mode:** the operator is free to move the robot in all directions using the navigation buttons on the GUI

**Automatic mode:** the operator can choose the destination location using the buttons labeled from 1 to 6, in this case the robot will start moving toward the destination by following the black line and reading the NG=FC tags located on the intersections.

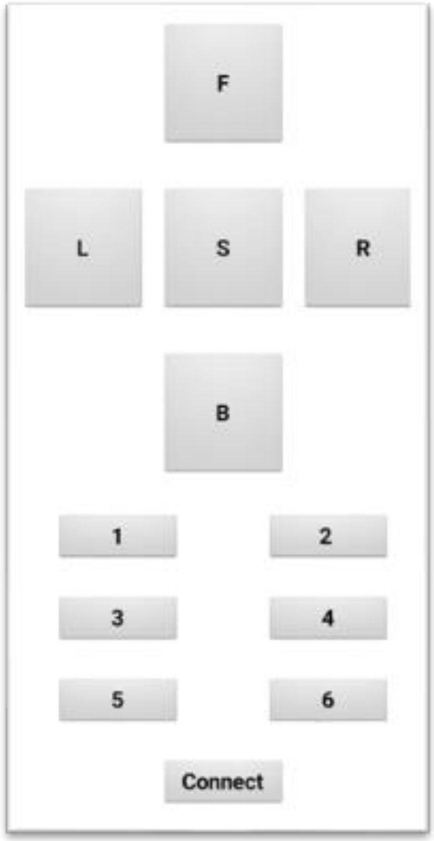


Figure 4.12: The implemented GUI of the mobile application

### 4.2.4 Step by Step system implementation

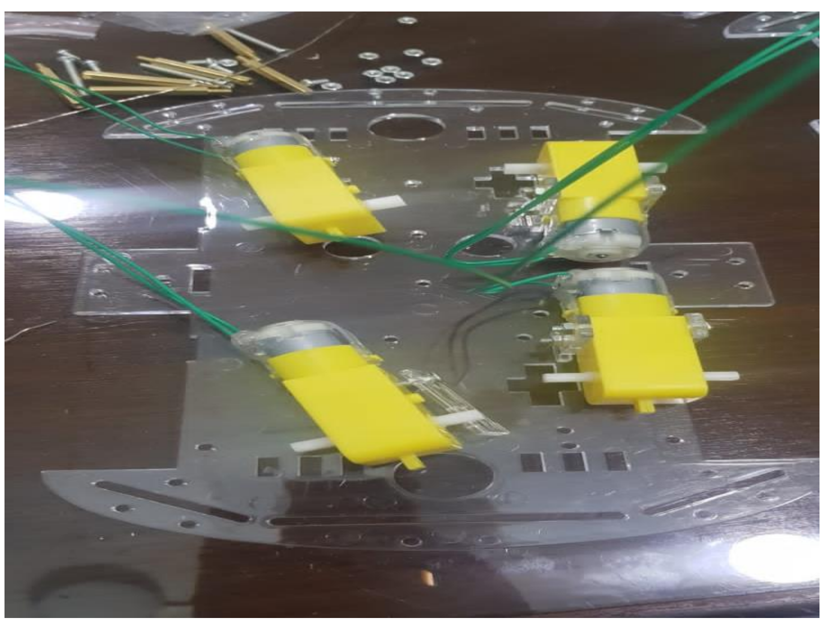

Figure 4.13: Instillation of the four DC motors on the Chassis.

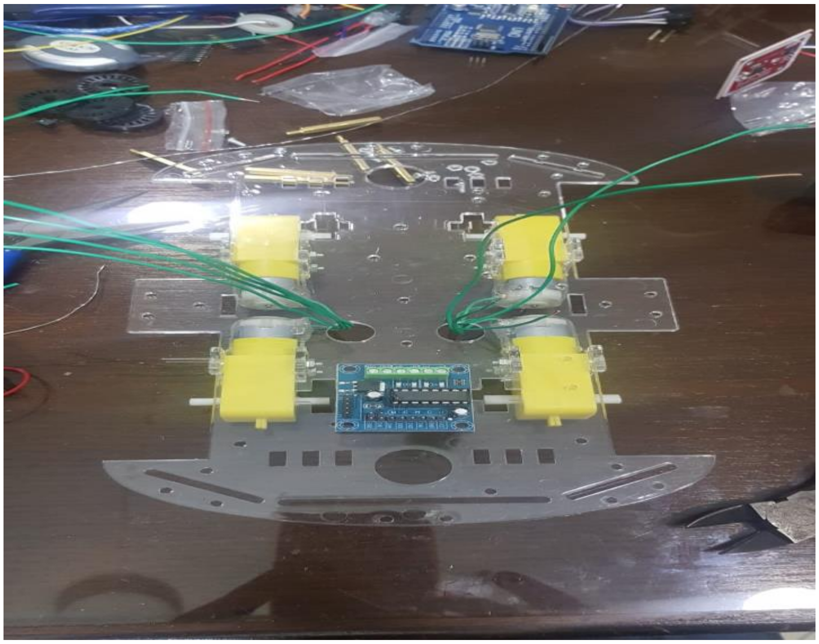

Figure 4.14: The installation of the H-bridge.

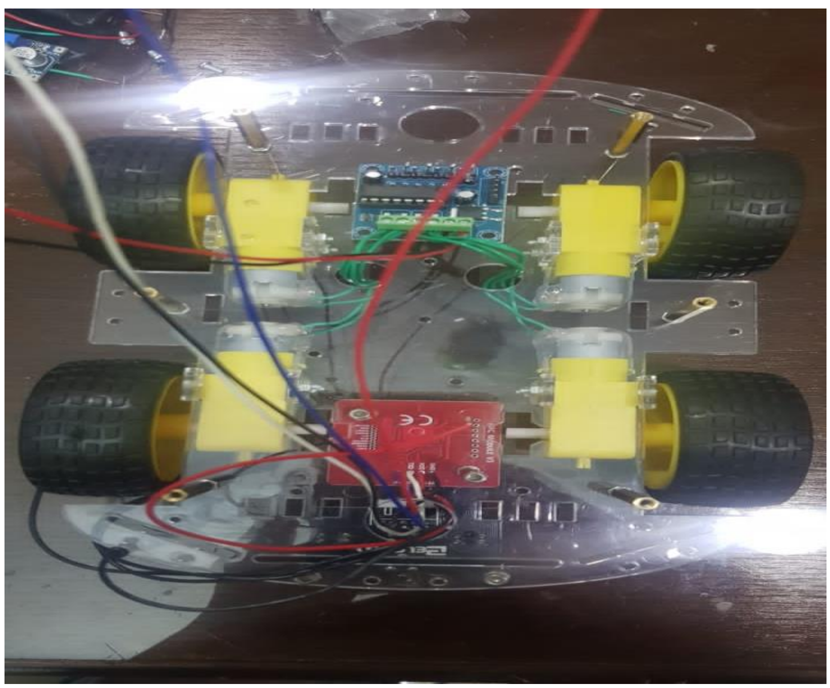

Figure 4.15: The installation of the tag reader and line following sensor.

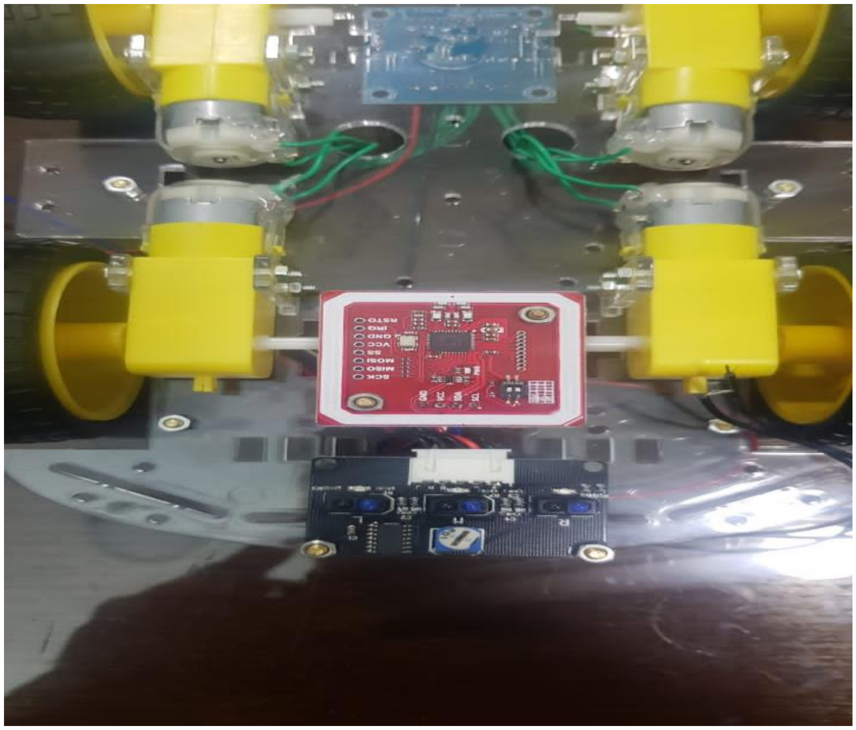

Figure 4.16: Bottom View of the Robot Chassis after installing the H-bridge, tag reader, and the line following sensor.

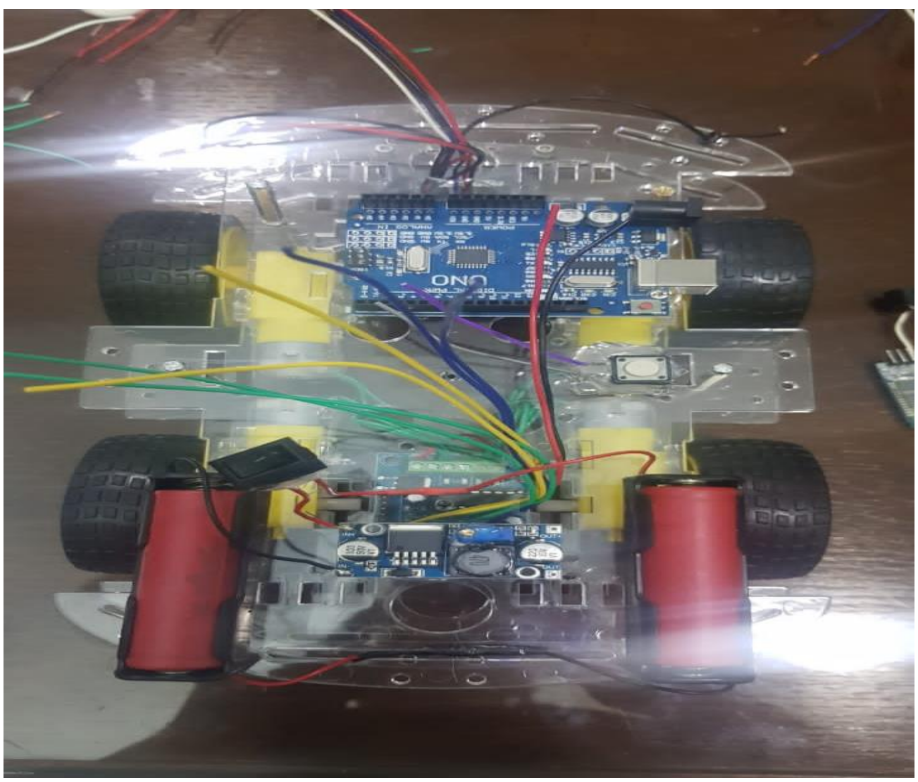

Figure 4.17: Installation of the power supply, Arduino uno, and batteries.

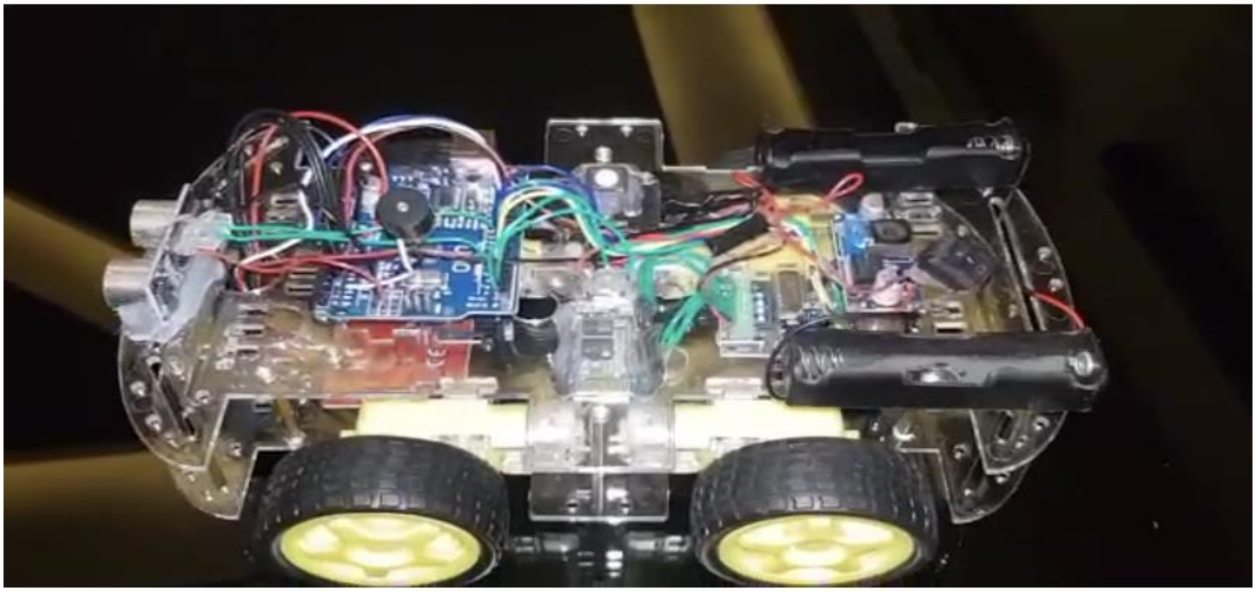

Figure 4.18: Side view of the final system.

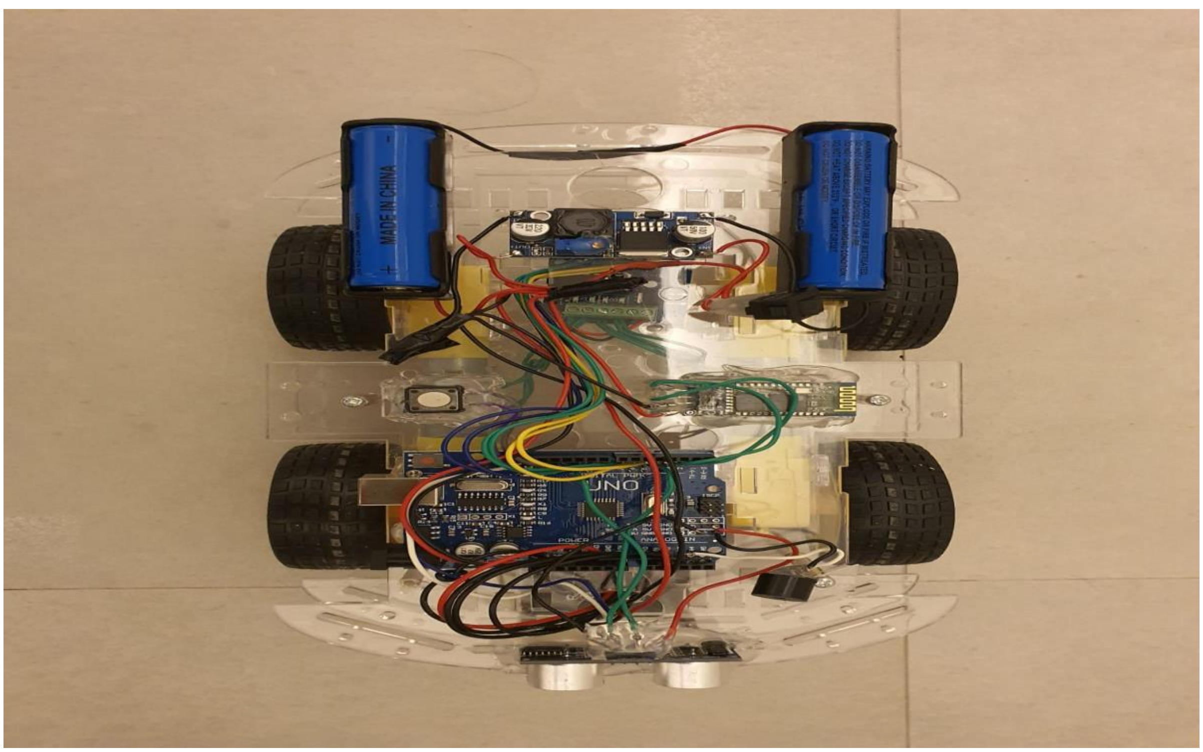


Figure 4.19: Top view of the final product.

# CHAPTER 5: EVALUATION

## 5.1 Requirements Evaluation

The first evaluation of the project will be in terms of the requirements that were determined at the beginning of the design stage to see if the implemented system met those requirements or not. The evaluation of the requirements is summarized in table 5.1.

Table 5.1: Requirements evaluation

| Requirements | Met or not |
|---|---|
| The system will consist of a robot prototype | MET |
| The path of the robot will be a line tray fixed on the ground | MET |
| The line tray shall be removed and re-installed easily | MET |
| The robot path must lead to the tables or rooms in restaurant, hotel, or hospital | MET for tables and can be applied for rooms using the same concept |
| The robot shall be able to reach the destination assigned by the admin of the system | MET |
| The robot shall be able to detect obstacles in its route | MET |
| The robot must return to its central station after delivering the order | MET but needs the guest to press the button |
| The robot shall be able to be controlled remotely and manually by an admin | MET |

| | |
|---|---|

## 5.2 Survey

The team conducted a survey to see people opinion regarding our project idea where surveys are considered as a strong evaluation tool for any project. The survey included the following questions:

- Did the pandemic of COVID 19 limit your visits to places such as hotel, restaurants, and cafes?
- Do you think gatherings in such places increase the spread of the infection?
- Do you think that a system like our system would decrease the possibility of transmitting the infection?
- Would you feel safer to visit a hotel or a restaurant knowing that they are using a robot like the one we made in this project?

The answers in these questions are shown in figures 5.1 to 5.4 consequently.

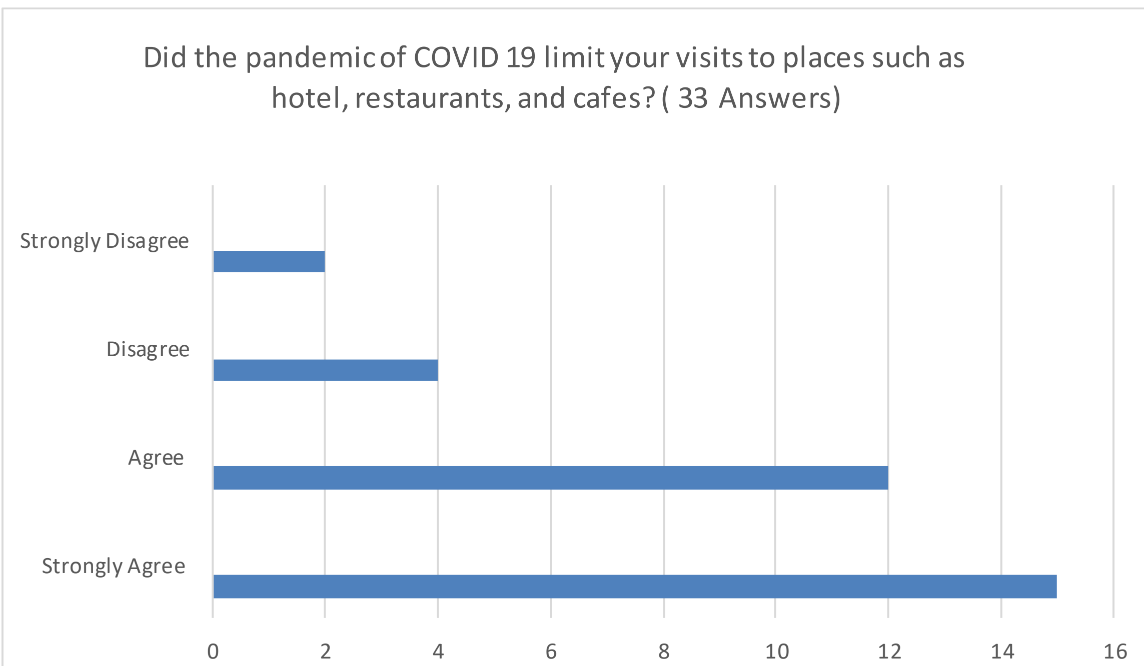


Figure 5.1: Survey question 1

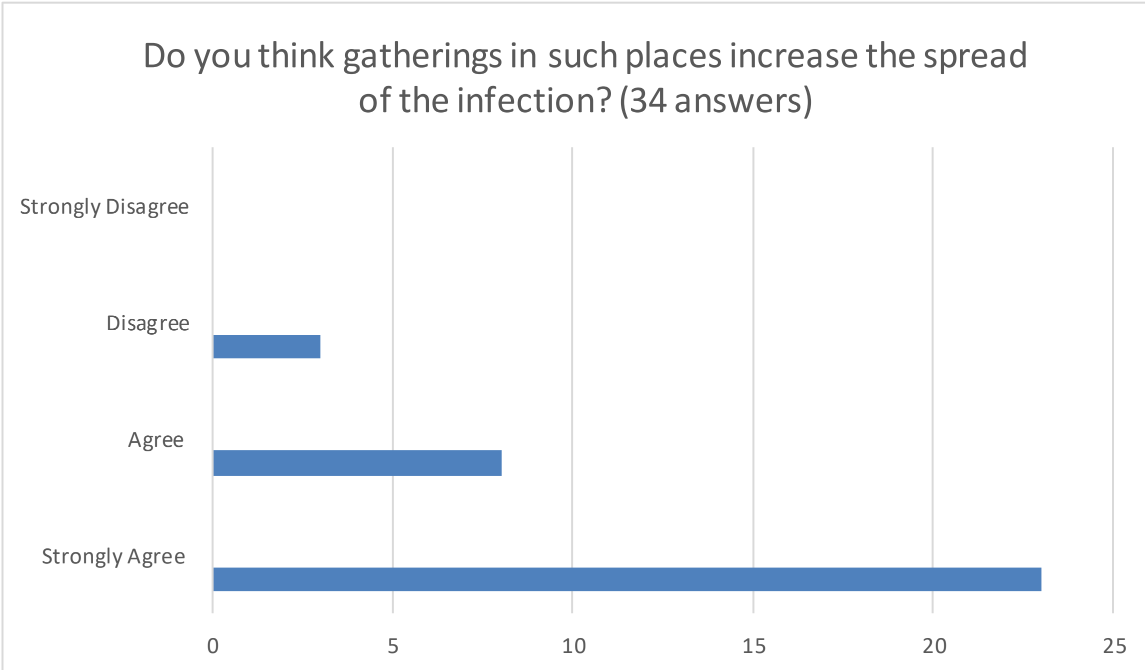


Figure 5.2: Survey question 2

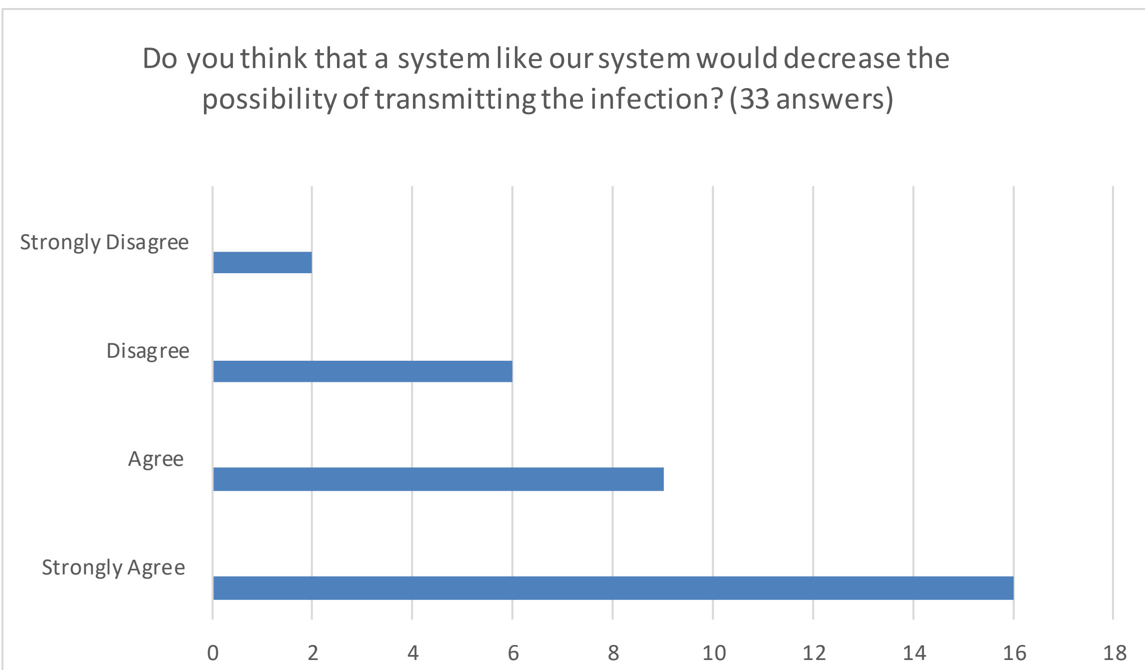


Figure 5.3: Survey question 3

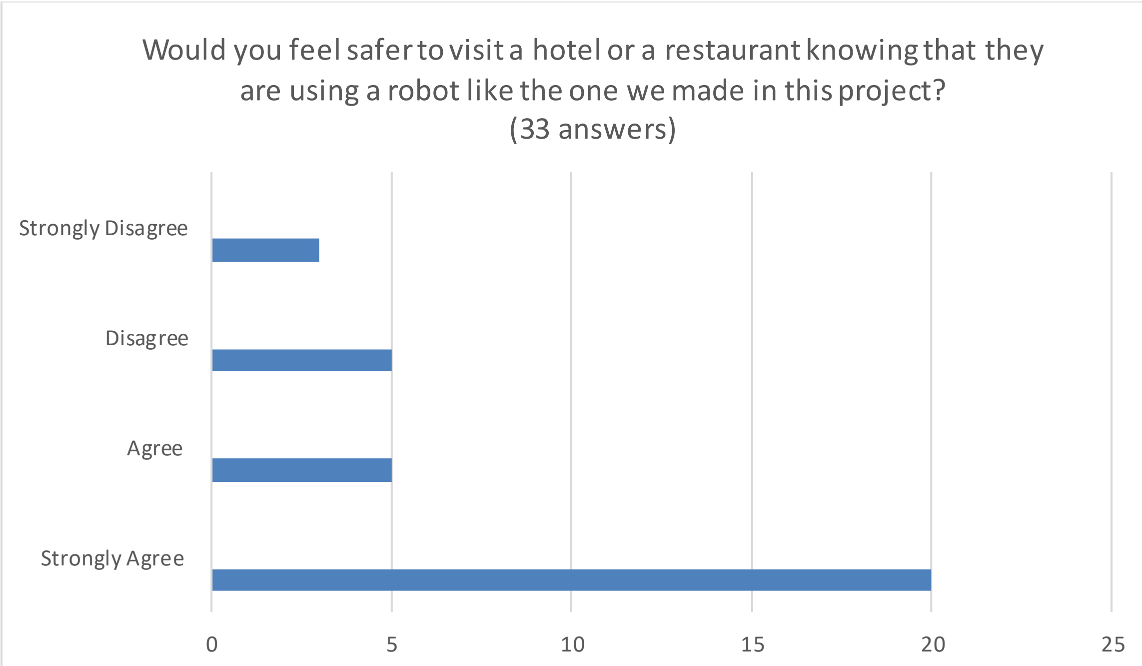


Figure 5.4: Survey question 4

The survey showed that people will feel safer and more confident to visit hotels, restaurants, coffee shops, and any places that uses a system like our system where they really think that a serving robot would decrease the possibility of transmitting the COVID-19 virus.

## 5.3 Project Impacts

### 5.3.1 Business Impact

The impact of the project on businesses will be significant because places like hotels, coffee shops, restaurants, etc. will attract more customers and visitors who will feel safer to be in these places that are using our system that eliminates the direct contact with the waiters and employees who might get the infection of COVID-19 from some customers and transmit it to others. Also our system can be a great business idea where we can sell it to restaurants, cafes, and even hospitals which are everywhere and in large numbers.

### 5.3.2 Economic Impact

Using our robot will help in easing the tough procedures that were imposed because of the pandemic of COVID-19. Public places like restaurants, coffee shops, hotels will be full of people again and this will support the economy and maintains the supply chains. Another good impact to the economy of the country will happen if a company is established to build and sell our robot to local and global clients around the world where this will make a high income to the country and supports the economy significantly.

### 5.3.3 Social Impact

Our system will give people the opportunity to gather again in public places and socialize where such gatherings are stopped in the past year of the pandemic of COVID-19. So with our robot people will be able to gout out again and meet their friends and relatives in public places to talk, socialize, and share their thoughts in a safe environment.

### 5.3.4 Environmental Impact

Our robot will have no bad or negative impact on the surrounding environment. It will be used in closed indoor places and will not affect its surrounding environment in any possible way.

# CHAPTER 6: CONCLUSION AND FUTURE WORK

## 6.1 Conclusion

At the end we are so satisfied with what has been done in this project in its both courses where we worked really hard to meet the aim, objectives, and the requirements of the project. We followed the timeline strictly and did our best to deliver the project in its best from. All the deliverables were delivered as planned and the system was implemented and tested successfully. This report tells the whole story of the project from the brainstorming level until the final implemented product.

## 6.2 Future Work

The space is open for new suggestions, ideas that could develop the system of this project in future. For example, a camera can be added to the robot to shoot a live video streaming for its route and show this live video to the admin on the mobile application screen. Another idea that can be implemented in future is to add another control method to the robot which is the voice commands where the admin can order the robot to go to a specific table or room. The field is open for innovation and creativity of students who will come after us and would be interested to improve our system and add new features and characteristics to it.

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# APPENDIX A

```
#include <Wire.h>
#include <PN532_I2C.h>
#include <PN532.h>
#include <NfcAdapter.h>
#include <SoftwareSerial.h>

#define rs A1
#define cs A0
#define ls A2

#define buzzer A3
#define doneb 12

#define echoPin 11
#define trigPin 4

#define pcs Serial

#define rmf 9
#define rmb 10
#define rme 6

#define lmf 7
#define lmb 8
#define lme 5

long duration;
int distance;
int rv,cv,lv;
String uid;
String t1,t2,t3;
String rxx;
int pos,target;
bool res;
```

```
PN532_I2C pn532_i2c(Wire);
NfcAdapter nfc = NfcAdapter(pn532_i2c);
SoftwareSerial ser(2, 3); // RX, TX



void setup() {
ser.begin(9600);

pinMode(trigPin, OUTPUT);
pinMode(echoPin, INPUT);

pinMode(rmf,OUTPUT);
pinMode(rmb,OUTPUT);
pinMode(rme,OUTPUT);
pinMode(lmf,OUTPUT);
pinMode(lmb,OUTPUT);
pinMode(lme,OUTPUT);

pinMode(buzzer,OUTPUT);
pinMode(doneb,INPUT);


t1="E0 30 52 D3";
t2="29 83 B6 B1";
t3="8D 9F 50 83";
}//setup





void loop() {
rxx=ser.readStringUntil('\n');



pos=rxx.indexOf("11");
if(pos>=0){
target=1;
serve();
}
```

```
pos=rxx.indexOf("22");
if(pos>=0){
target=2;
serve();
}

pos=rxx.indexOf("33");
if(pos>=0){
target=3;
serve();
}

pos=rxx.indexOf("44");
if(pos>=0){
target=4;
serve();
}

pos=rxx.indexOf("55");
if(pos>=0){
target=5;
serve();
}

pos=rxx.indexOf("66");
if(pos>=0){
target=6;
serve();
}

if(rxx.indexOf('F')>=0){rob_forward();}
if(rxx.indexOf('B')>=0){rob_reverse();}
if(rxx.indexOf('R')>=0){rob_right();}
if(rxx.indexOf('L')>=0){rob_left();}
if(rxx.indexOf('S')>=0){rob_stop();}
```

```
}//loop

void buzzing(){
digitalWrite(buzzer,1);
delay(200);
digitalWrite(buzzer,0);
delay(300);
}



void measure(){
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);
duration = pulseIn(echoPin, HIGH);
distance = duration /58.2;
}


void gettag(){
nfc.tagPresent();
NfcTag tag = nfc.read();
uid=tag.getUidString();
}


void line_follow(){


rv=digitalRead(rs);
lv=digitalRead(ls);
cv=digitalRead(cs);



if ((rv==0)and(lv==0)and(cv==0)){//all see
rob_stop();
digitalWrite(buzzer,1);
delay(1500);
digitalWrite(buzzer,0);
}
```

```
if ((rv==0)and(lv==1)and(cv==1)){//right see
rob_right();
delay(100);
rob_stop();
}


if ((rv==1)and(lv==0)and(cv==1)){//left see
rob_left();
delay(100);
rob_stop();
}


if ((rv==1)and(lv==1)and(cv==0)){//center see
rob_forward();
}




}//line follow



void serve(){

line_follow();
gettag();

if (target==1){
if (uid.indexOf(t1)>=0){
proceed_right_go();
}
}


if (target==2){
if (uid.indexOf(t1)>=0){
proceed_left_go();
}
}
```

```
if(target==3){
if (uid.indexOf(t2)>=0){
proceed_right_go();
}
}


if(target==4){
if (uid.indexOf(t2)>=0){
proceed_left_go();
}
}


if (target==5){
if (uid.indexOf(t3)>=0){
proceed_right_go();
}
}


if (target==6){
if (uid.indexOf(t3)>=0){
proceed_left_go();
}
}

}


void proceed_right_go(){
rob_right_search();
line_follow();


while(digitalRead(doneb)==1){
digitalWrite(buzzer,1);
delay(50);
digitalWrite(buzzer,0);
```

```
delay(500);
}

rob_right_search();
line_follow();
rob_left_search();
line_follow();
}

void proceed_left_go(){
rob_left_search();
line_follow();

while(digitalRead(doneb)==1){
digitalWrite(buzzer,1);
delay(50);
digitalWrite(buzzer,0);
delay(500);
}

rob_right_search();
line_follow();
rob_right_search();
line_follow();
}

void rob_forward(){
measure();

if(distance>15){

digitalWrite(rmb,0);
digitalWrite(lmb,0);

digitalWrite(rmf,1);
digitalWrite(lmf,1);
}
}
//////////////////////////////
```

```
void rob_stop(){

digitalWrite(rmb,0);
digitalWrite(lmb,0);

digitalWrite(rmf,0);
digitalWrite(lmf,0);

}
//////////////////////////////
void rob_right(){

digitalWrite(rmb,1);
digitalWrite(lmb,0);

digitalWrite(rmf,0);
digitalWrite(lmf,1);

}
//////////////////////////////
void rob_left(){

digitalWrite(rmb,0);
digitalWrite(lmb,1);

digitalWrite(rmf,1);
digitalWrite(lmf,0);

}
//////////////////////////////
void rob_reverse(){

digitalWrite(rmb,1);
digitalWrite(lmb,1);

digitalWrite(rmf,0);
digitalWrite(lmf,0);

}
//////////////////////////////
void rob_right_search(){

digitalWrite(rmb,1);
digitalWrite(lmb,0);

digitalWrite(rmf,0);
```

```
digitalWrite(lmf,1);

while (rv==1){

digitalWrite(rmb,1);
digitalWrite(lmb,0);

digitalWrite(rmf,0);
digitalWrite(lmf,1);

rv=digitalRead(rs);
}

}
/////////////////////////////////
void rob_left_search(){

digitalWrite(rmb,0);
digitalWrite(lmb,1);

digitalWrite(rmf,1);
digitalWrite(lmf,0);


while (digitalRead(ls)==1){
digitalWrite(rmb,0);
digitalWrite(lmb,1);

digitalWrite(rmf,1);
digitalWrite(lmf,0);

}

}
```

# APPENDIX B

## IEEE Standards

- IEEE 802.15.1-2002 for telecommunications
- IEEE 872-2015
- IEEE 2700 standard for sensors performance
- IEEE 133-1985

# APPENDIX C

**Gantt chart**

| **Tasks** | **Oct, 2020** | | | | **Nov, 2020** | | | | **Dec 2020** | | | | **Jan, 2021** | | | | **Feb, 2021** | | | | **Ma, 2021** | | | | **Apr, 2021** | | | | **May, 2021** | | | | **June, 2021** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **W1** | **2** | **3** | **4** | **W1** | **2** | **3** | **4** | **W1** | **2** | **3** | **4** | **W1** | **2** | **3** | **4** | **W1** | **2** | **3** | **4** | **W1** | **2** | **3** | **4** | **W1** | **2** | **3** | **4** | **W1** | **2** | **3** | **4** | | | | |
| Choosing the idea | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Writing the abstract and the literature Review | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Choosing the approach | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Finalizing the design | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Choosing the components | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Writing the progress report | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ordering the components | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Assemble the robot | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Programming the microcontroller | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Developing the mobile application | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Testing the hardware | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Connecting the robot with the application | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Complete system testing | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Writing the final report | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |